No. 4. July, 1862. 2s. 6d.

THE Popular Science Review.

A QUARTERLY MISCELLANY OF ENTERTAINING & INSTRUCTIVE ARTICLES ON SCIENTIFIC SUBJECTS.

EDITED BY JAMES SAMUELSON.

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No. V., October 1, 1862,

Will contain, besides other interesting and instructive matter,

NOTES OF THE EXHIBITION (continued from No. IV.), in which the following departments will be described by the contributors to the POPULAR SCIENCE REVIEW.

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THE AGRICULTURAL IMPLEMENTS (concluded from No. IV.)

THE PHILOSOPHICAL INSTRUMENTS.

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AN ACCOUNT OF THE PROGRESS OF SCIENCE SCHOOLS AND PROVINCIAL SCIENTIFIC INSTITUTIONS; for which communications are invited by the Editor.

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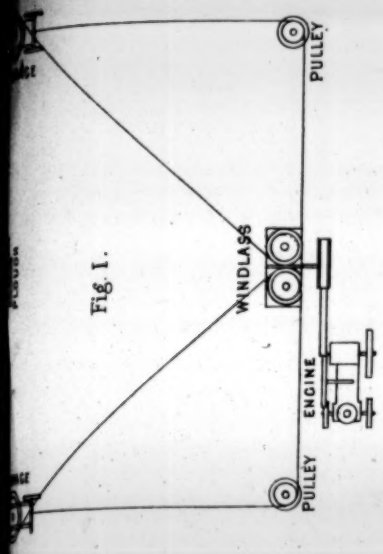

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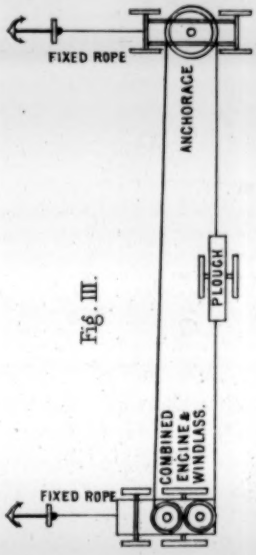

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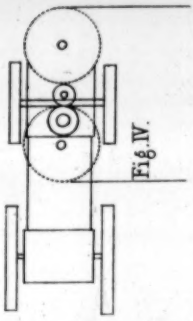

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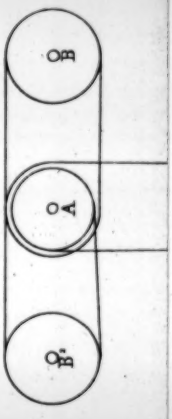

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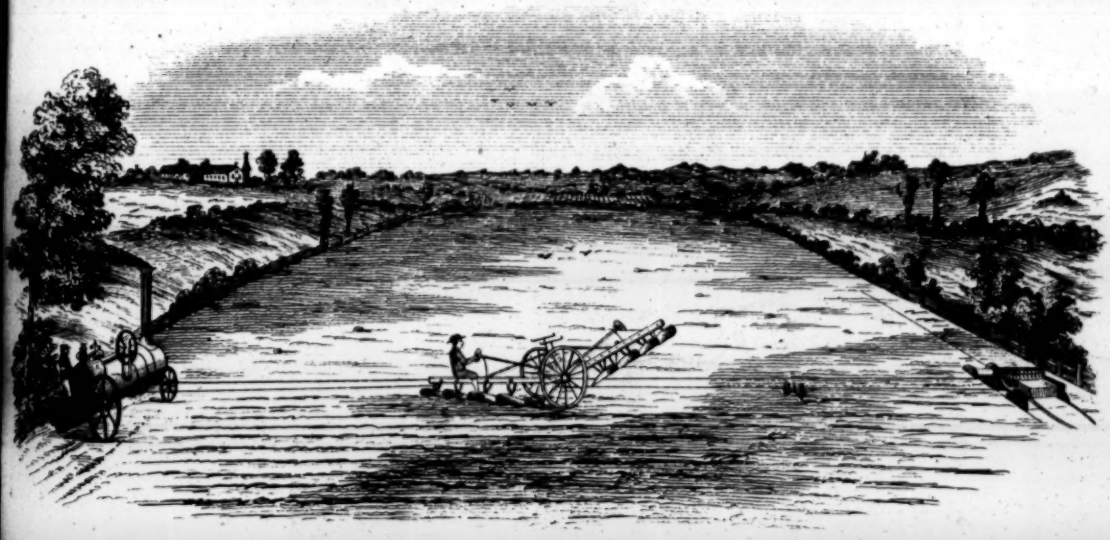

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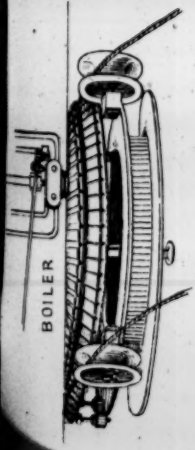

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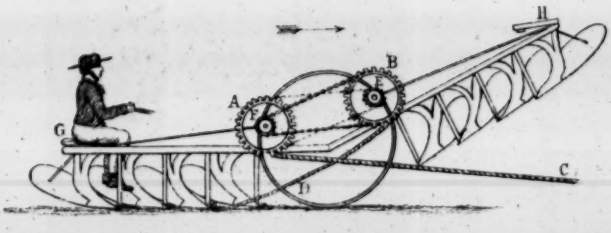

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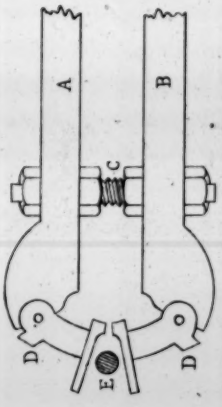

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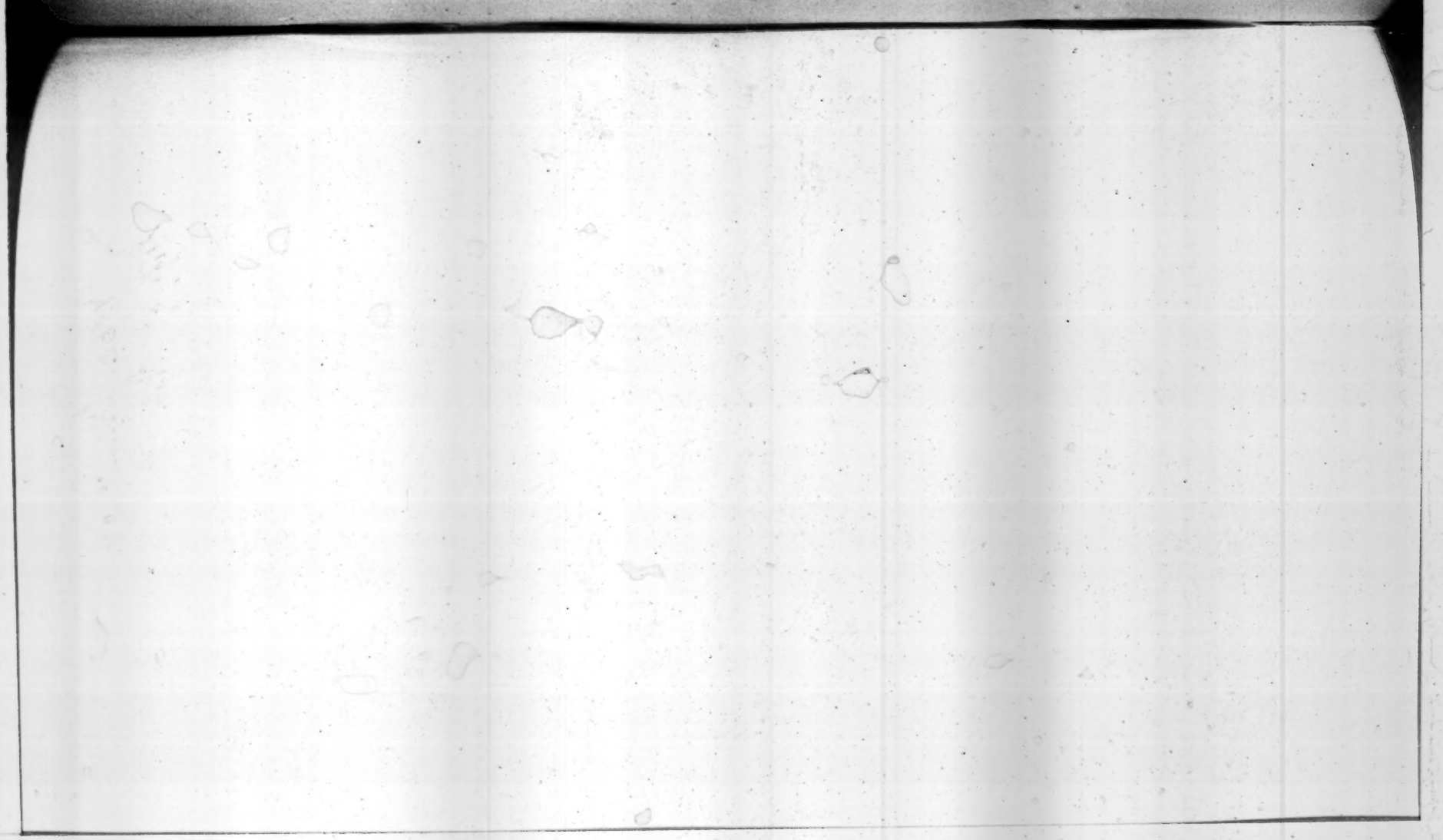

1866, April 27.
Gift of Wm. James,
of Boston.

THE EXHIBITION OF 1862.

FEW of our readers who visited the Great Exhibition of 1851 will have forgotten the first effect produced upon their minds by the beautiful crystal edifice and its contents.

Strong men wept, they knew not wherefore; some were completely bewildered with the surrounding scene; and all who trod the maze of courts and avenues were glad, after a brief space of time, to seek some quiet corner and rest their wearied minds and bodies; for the multiplicity of novel objects, the varied costumes of the visitors, the grand arching roof of crystal overhead, the sweet-scented flowers and still sweeter strains of music, the wide-spreading trees in full leaf, crystal fountains, silent statues, sparkling jewels, and a thousand other attractions, riveted the attention by turns, drawing it first to this side and then to that, until the spectator walked as in a dream, and, unable longer to appreciate the wonders around him, sank down exhausted and satiated with the feast of beauty, grace, and novelty.

Since then we have had, and still retain, the Crystal Palace of Sydenham, far eclipsing that of 1851 in external beauty, and furnished with all the attractions of art and nature within and without its walls of crystal; the "Exposition" of Paris, concentrating within its precincts all the works of art and industry of which the Continent could boast. Manchester, Dublin, and other cities have followed in the wake; and now, after a lapse of eleven years, we are again called to the metropolis of Great Britain to witness the progress of the industry of mankind in a second "World's Fair."

But, alas! the fairy tale of childhood has lost its charm. The light Crystal Palace has given place to the solid edifice of brick and stone, and the directors of this new enterprise say to us, as plainly as they can speak through their brick walls: "You have been humoured and indulged in the fancy, now you must descend to the fact. Formerly we found it necessary to lure you through the senses, but now you are no longer children. A decade of years has changed the wants and tastes of your race, and you must therefore accommodate yourselves to circumstances, and be content to study the material progress of a utilitarian age."

With this view, then, the transparent walls of crystal are converted into impenetrable brick; light, ornamental iron arches give place, here and there, to temporary wooden ones, in order that more space may be afforded for the exhibition of works of industry; and everything, from the porcelain fountain to the solid refreshments, speaks of work—hard, earnest work, and its rich golden fruits.

But the contrast with the Exhibition of 1851 is calculated to remind the spectator, not only of the material progress which has been made in the interim, but also of sad events that have occurred since then, and of others which are now taking place.

We are sure the zealous noblemen and gentlemen who have taken so active a part in the execution of this work will pardon us; nay, they will, we think, agree with us, when we say that there is a falling off in the grace and harmony of the display, owing to the absence of one who combined the solidity of our nation with the taste which characterizes his own, and to whose intelligence the success of the first Exhibition was mainly due. The presiding genius of the place seems to manifest, by the carelessness of her attire, her esteem for the Prince who prepared her first palace and was removed before the second was ready for her reception.

Then there is another "absence" by which this great bazaar of all nations is rendered conspicuous. We miss (smile not, reader!) the long rows of Yankee hams, and pork, and cotton bales; ay, no one will deny that we miss those; the flour-barrels, full or empty, the heaps of gutta-percha soles and toys; we miss their rocking-chairs and their reaping-machines. For their cotton bales are now being employed to make bonfires, or to protect brothers from the murderous fire of brothers at home; and their reaping-machines are converted into scythes with which Death reaps his dread harvest.

Fortunately for us we have peace at home, although the casual visitor who saunters down the great aisle would hardly think so; for the display of rifled ordnance; of thick plates of iron battered by deadly missiles, and of small arms grouped in stars and pyramids, would lead the stranger to suppose that we were either on the eve of a great war, or had just concluded one of long duration. Nor would his surprise be diminished if he were told that all these terrible implements of warfare had been devised in order to enable us to maintain peaceful relations with a neighbouring people whose contributions to our Show are the admiration of all beholders.

Strange, then, and of a mixed kind, are the thoughts suggested by a cursory glance at our Great Exhibition of Industry, Science, and Art; but we must do the bidding of the "Com-

missioners," must cease to moralize, and take the world as we find it, encased in brick and stone. We must cast an inquiring glance into the Courts and Annexes—each an exhibition in itself—and endeavour to note the progress of the sciences. To do this as completely as our space permits will be our aim, and with this view we invite our numerous friends and contributors to send us their impressions, their NOTES OF THE EXHIBITION.

THE AGRICULTURAL IMPLEMENT DEPARTMENT.

BY HOWARD REED.

IN 1851 we well remember to have turned, with something of disgust, from the magnificent department where Russia displayed her malachite furniture, rich mosaics, and splendid tissues of gold and silver, to the bales of cotton, the maize, and pickled pork of America. They were strikingly opposed to one another, and it required some minutes before we could appreciate the force of the contrast. The sumptuous display in the one represented the gratification of the few; the vulgar but practical essentials in the other represented the comfort of the many. In the one we beheld the luxurious adornment of the palatial residence; in the other the solid comforts of cottage homes. As we gazed on the one, we beheld the means by which the land from Canada to the Mississippi had been subjected, cities raised as by enchantment, deserts peopled in a season, the whole country knitted together by iron ways, which cross the track of the Indian still fresh amid the dead leaves. The other spoke of popular stagnation, and recalled the lie with which Voltaire flattered and lulled Louis XV. in the midst of his court.

> Cette splendeur, cette pompe mondaine
> D'un règne heureux sont la marque certaine.

There will be found the same revulsion of feeling in favour of this pioneer force in the Eastern Annexe of the International Exhibition, although one does appear to be leaving all that is beautiful behind when penetrating the tunnel by which it is approached. When the mind is fully awakened to the utility of agricultural machinery, to the important part it plays in the subjection of the waste, the culture of much of the raw material which constitutes our wealth, and the production of food which supports man while he creates out of the raw material substances which contribute to our comfort or the forms which gratify our taste; the charms even of high art will be found

to possess a formidable rival in the homeliness of practical science in its working dress.

Here may be observed the drainer's tool, which has converted into a fertile field, the miasmic haunt where fever lurked, and whence he has made his deadly raids upon the neighbouring centres of population; here is the lineal descendant of the crooked Roman plough once guided by the good Cincinnatus, and which, improved in form, has upheaved the tenacious clays of England to the keen disintegrating tooth of frost and harrow, changing a churlish receptacle into a fertile seed-bed. Again, observe the automaton machine, which deposits the seed in regular lines at an equal depth, accompanied by nourishment suited to its earliest development. Near it, the implement which follows when the weeds appear, and lays low those enemies of the cereal blade. Then we have the iron reaper, with his keen swift sickle-edge, before whose radical progress the grain bends and falls for preservation when ripened by the sun of summer. And, lastly, behold the great steam-driven flail, which at once lashes the grain from its retreat and assorts it for use. These are but a few typical forms, but they suffice to suggest the part played by machinery in the great work of food-production, by which the country districts have been drained of their population. The last census shows a singular decrease in the simply rustic element. The wilds of Australia, the back woods of America, the gold-gains of auriferous regions, and the temptations of large wages in the mills, iron-works, and railway enterprises of our own country, have drawn Hodge from his quiet village in spite of the law of settlement, and yet the business of the farm goes on as well as ever. The area of land under cultivation is increased—its fertility augmented. Machinery has enabled us to effect the solution of an economic problem. Whereas in a savage state one man can barely obtain enough from the soil for the supply of his own wants and those of his family, we have, through the use of machinery, attained a state of civilization, in which the labour of *one* nearly suffices to supply the wants of *four* men, so that while one is retained in the field, three are sent to the towns to work for the World's Great Bazaar, and are supported while thus increasing the national wealth. The results, therefore, of human skill in other departments of this Exhibition may be regarded as directly due to the implements of husbandry here less attractively displayed, because they have set men free from the culture of the soil and the production of essential food, to minister to the more luxurious wants that always characterize the progress of civilized man. Preserving, then, a due sense of the relationship which subsists between the delicate tissues of the loom, the ennobling works of art, and the farmer's wheeled

plough—or, better still, the steam-drawn cultivator—a passing glimpse of the contents of this matter-of-fact section cannot fail to afford satisfaction.

About 140 manufacturers of agricultural implements have taken advantage of the opportunities here afforded to them for the display of their goods. All the principal firms are represented, some by a few main articles, others by a complete exhibition of everything made in their workshops. Here we perceive barrows, boilers, and bone-mills; carts, chaff-cutters, and churns; fire-engines, flower-stands, and forks; garden-tools, grinding-mills, and grubbers; haymakers, horse-rakes, and hurdles; mangers, mangles, and millstones; pails, ploughs, and pumps; rakes, reaping-machines, and rollers; scythes, spades, and steam-engines; thrashing-machines, tree-guards, and turnip-cutters; waggons, washing-machines, and water-carts; indeed, more than can be well enumerated.

But it is not our intention to follow this alliterative category. Were we to attempt it, there would be no great difficulty in showing that Progress is as well represented in the Eastern Annexe as in other departments of this World's Fair. A walk through this section will convince the visitor that its contents are not excelled elsewhere either in contrivance or workmanship, and those who remember the Agricultural Implements in 1851 will perceive surprising advances in several directions. Interest, for such reasons, may gather around the thrashing-machines, reaping-machines, the machines used in the preparation of food, engines, and the like, but it fairly culminates in *the Steam Plough*. It is doubtful whether any other section of the Exhibition can point to such an achievement as this. In 1851 there was no steam plough; there were drawings of impossible machines bearing that name in the Patent-office, and in 1855 scarcely a furrow in the country had been turned by this mechanical surprise; but now what crops of wheat and mangolds are sending down their roots and luxuriating in the deep steam-stirred subsoil! And all this accomplished in seven years! Think for a moment of the indomitable perseverance of the Buckinghamshire tenant-farmer Smith; of the courageous and inventive Fowler; of the sanguine Canadian Romaine; of Boydell, and Usher, and Williams, and the brothers Howard; of patents obtained and abandoned; of trials innumerable, public and private, and we have here such a story as the previous forty years could not tell, granting always that the progress of that period had much to do with the development of this.

In 1851 our progressive farmers were only beginning to think of the advantages of *autumn fallowing*, of the clearing of land during August and September, of its preparation for the early sowing of the root-crop, and had just discovered how

insufficient our horse-power was for such supplementary labour. Bentall and Coleman had furnished the desired land-parers, but we yet wanted the auxiliary force. Scarcely anybody at that period had conjectured the possibility of abandoning the dead fallow system, so long in clay districts a recognized process in all programmes of rotation; nor, indeed, was it until 1855 that the dawn of such a day was heralded to those advanced ones who are always watching on the mountain heights where the first streaks of light are visible. But, what a change have we now! We are at home with Fowler's steam plough and Smith's "smasher." The squire's horse takes no more heed of the engine traversing the headland than of the hare crossing the road; dead fallows are virtually abandoned; the clays are reclaimed; they are absolutely to be considered of some use to us, and the land now overshadowed by broad blade and glossy leaf, was cleared and laid up last autumn to be pulverized by the glacial influences of winter and fertilized by the free access of air and rain. This is a glorious, a highly poetical revolution; and it has occurred in less than ten years! Calculate, if you can, the effect which may be produced by the untiring toil of some two hundred of these steam-driven cultivators—ripping up the solid pavement made by the pressure of the horses' feet and the sole of the team-drawn plough, impervious alike to rain, and root, and air. A new mine is opened—or, in other words, the corn-growing area of our island-home is extended, doubled, trebled—not horizontally but vertically. You may search in vain for inventions in other departments of this Exhibition, likely to produce such singularly advantageous effects upon the future of our country.

We will not now enter upon the consideration of ultimate advantages, but will endeavour to narrate the steps which led to the present state of the rope-traction system of steam-tillage. It would occupy too much space to tell the whole history, taking our readers back to 1630, or beginning at a later date, rendered memorable by an enthusiastic inventor who induced several neighbours to part with their horses because he had designed a machine to supersede them. Such a trip into the past would be very pleasant, but we shall just fall in where Mr. Fowler, having solved the difficulty of draining land by steam, was quick enough to perceive that the attempt to do one thing had given him the power to do another, and that, though draining might be better done by men than by steam, ploughing might be performed more cheaply and conveniently by steam than horses. This was in 1855, when intelligent farmers were wishing for horses without feet, and implements that would work night and day during the critical six weeks of September and October. The windlass he used for the mole plough served

his purpose, so that he had only to invent a plough. A glance at the diagram (Pl. XXII., fig. 1) will show the windlass, which consisted of two drums on vertical axes, in a frame, set halfway down one side of the field, and driven by a portable engine. The two wire ropes led off from the drums in an angular direction to the anchorages, as represented, meeting in the plough. Each anchorage consisted of a low truck with four sharp disks instead of wheels, which cutting deeply into the ground, offered great resistance sideways, whilst they were easily pulled forward through the soil. A large sheave or grooved wheel was placed underneath, round which the wire rope passed, and the truck was weighted with earth to hold it firmly down. The ropes attached to the anchorages and passing round the pulleys at the corners of the field were so commanded by the men at the engine that the anchorages could be pulled forward by means of them, so as to be always opposite the work.

The "balance" plough, exhibited in 1856, continues pretty much as it was. It consisted of two sets of four plough-bodies rigidly fixed at opposite ends of a long beam-frame, which was balanced in the middle upon the axle of a pair of carriage-wheels (fig. 2). The hauling-rope, in this case attached a little below the centre, exerts force on the set of ploughs, on which the man is seated, in the direction of the arrow, while the slack rope dangles in the wake of those ploughs in order to pull the implement back and draw the opposite set the reverse way. The steerage was simply effected by a man riding on the implement, who was enabled to lock the axletree of the wheel. The anchorages in 1856 were made self-moving, so as to work without any dependence upon the men at the engine. Not many months after this, in 1857, an ordinary engine was placed upon the strengthened frame of the windlass, and the whole was made to traverse the field-headland by winding up a rope anchored forward. The machinery as it then was is represented in fig. 3. Let the engine be supposed to be entering one end of an oblong field with its train of apparatus. It makes its way to the opposite end. In one corner it leaves the anchor, and then proceeds to take up its own position in the other. The rope spans the distance between, and when steam is up, hauls the plough to and fro, the engine and anchor drawing themselves forward by the ropes anchored forward along the opposing headlands as the plough requires a new bite. Thus we see the matter simplified, and rope and power economized. The advance was certainly great, so much so as to merit the £200 prize offered by the Highland Society; but still the machinery was too ponderous and expensive for ordinary farm use.

Mr. Fowler in 1858 made another important step. His machinery underwent a complete revision. A new windlass

with two drums (fig. 4), each four feet in diameter, on vertical axles, and bearing upon their circumferences four grooves, had taken the place of the old one. Here was a fresh economy of rope and of power. In place of two long ropes which wound and crushed upon themselves in a manner which greatly injures metal cordage, there was established an endless rope, simply passing from the moveable engine on one headland of the field to the moveable anchorage at the other, but with a sufficient surface-grip in the drum-grooves already mentioned to keep it from slipping. The rope was divided into lengths, joined by hooks and eyes, and could be accommodated to the fluctuating length of the furrow. This apparatus has peculiar interest attaching to it. It decided at Chester the important case *Steam* v. *Horse-power. It established, in fact, for the first time, that steam is an economical substitute for horse-power,* and in so doing won for its inventor the prize of £500. The horse and the steam-drawn plough were tested side by side; upon light land there was shown to be a saving of 2*s.* 9½*d.* an acre, while upon heavy land the saving by the employment of the steam plough appeared to be 5*s.* 8½*d.* an acre. In the latter part of the same year it was found possible to dispense with one of these two drums, and to introduce the arrangement shown in fig. 5. The propulsion of one in place of two drums, beneath the frame of the locomotive engine, again economized power, or, in other words, coal.

At a subsequent period the implement was very much reduced both in size and price, and so lightened that whilst at the meeting of the Royal Agricultural Society at Canterbury, in 1856, it seemed content to grapple with two-horse work at a maximum rate of seven acres a day, it now made light of four-horse work at the rate of eleven acres, and executed that which was impracticable for horse-power at a maximum rate of six acres a day, drawing, at a much more rapid rate than horses could attain, three ploughs up hill and four down, and with a furrow that would require six horses to turn at their own pace.

We will now describe Mr. Fowler's apparatus as it performed last year at the Royal Agricultural Society's meeting at Leeds, where it was again distinguished above all competitors on the prize-list. Upon one headland or side of the field (fig. 6) is seen the engine; on the other the anchorage; the plough is between them. As the engine is the point of resistance, towards which the plough is hauled one way, so the point of resistance the other way is the anchorage. These two points, always opposite, gradually shift, little by little, from end to end of the field, the land between them being left inverted. The engine is of an ordinary character, but beneath its boiler it bears a large drum or wheel of peculiar construction, actuated by a

vertical axis descending from the crank-shaft. In order to pull a heavy implement, like a four-furrow plough, by means of an endless rope, which only embraces, but is not attached to a cylinder, it is clear that some ingenious arrangement is needed to prevent the rope from slipping under great strain. We have seen how this difficulty has been provided for; but we have yet to notice a better contrivance than those described. It had been found in practice that when the plough was in severe work the rope could not obtain sufficient hold of the drum-surface to overcome the opposing resistance, and thus, while the drum revolved, it ceased to afford motion to the rope. Instead of requiring a turn of the rope in grooves, this new drum grasps the rope in a single groove, the rope making but one half-turn round it (fig. 7). A common groove somewhat resembles the letter V in form. The power of such a groove to hold the rope against a heavy strain depends upon its nipping it. With this view, the drum consists of two iron disks bolted together—see section (fig. 8)—and the V groove is formed of pairs of knuckle-jointed nipping-pieces, so placed, in pairs, round their peripheries as to collapse upon the rope when it presses upon them. The anchorage has been described. Nothing more need be described with respect to the four-furrow plough save the ingenious method of keeping the rope always tight. (See fig. 2.) The advantage of such a contrivance will at once be seen by those who consider the difficulties that would continually arise from the varying lengths of furrows where hedgerows are not parallel.

We believe there are about one hundred of these steam-ploughs now at work in England, some tilling the light lands; but most of them rending the solid hoof-pressed pavement, which, beneath the cultivated surface of our clays, impedes alike the entrance of air, rain, and rootlet. In France there are several. Upon one farm in Hungary there are eight at work. Russia is employing them to bring her thinly-populated plains into cultivation. Our colonies possess them; in Algeria they are preparing a seed-bed for the cotton-plant, and even now two of them on the banks of the Nile stand face to face *with the common parent of all ploughs.* Here, it is displacing horse-labour, heralding improved methods of culture, and making provision for the demands of increasing population; abroad, it is fertilizing the waste, subduing prejudice, befriending the ardent and enterprising, and lending its shoulder to political revolution and national regeneration wherever they may be wanted.

It is no uncommon thing to find oneself rung out of the Kensington Exhibition before a tithe of the appointed work

has been accomplished; and now, ere we have even finished with the steam-plough, our remarks must be brought to a close. We have yet to notice the methods of steam-culture advocated by Mr. Smith, the brothers Howard, Romaine, Halkett; indeed, Mr. Fowler is scarcely done with, for no allusion has been made to the manner in which he adapts his apparatus, by means of a fixed windlass, to the requirements of those who do not wish to purchase a new engine specially designed to work the endless rope. But, in this particular, he has some decided improvements to show at the Battersea meeting, which, with other inventions, may well form the subject of our next communication.

DESCRIPTION OF PLATE XXII.

Fig. 1. The boundaries of a ten-acre field or plot of land are here represented. The *plough* begins at one corner of the field on the side opposite to the *engine*, and plies its course, taking four furrows forwards and four backwards between the *anchorages*, which are gradually advancing to the *pulleys*. When these are on a line with the windlass, the apparatus can be moved round to cultivate a similar plot on the other side of the engine, a hedgerow affording no obstruction to the passage of ropes.

Fig. 2. The following is an explanation of the automatic contrivance for gathering up the slack rope without loss of time. Two small drums, *a* and *b*, are mounted upon the plough frame, near the middle, the ends of the two wire ropes being wound several times round each, so as to allow of being paid out in case of a lengthening furrow, or gathered up for shorter work. Suppose the plough to be going in the direction of the *arrow*, the rope *c* will be the pulling rope, and *d* the trailing or slack rope. At starting, the rope *c* causes the drum *a* to revolve; by means of an endless pitch-chain this drives the pinion *e* on the axis of the drum *b*, which rotating with a velocity five times greater than that of the drum *a*, gathers up the slack rope *d* until the whole of the endless rope up and down the field is tight, when the rope *c* can no longer cause the drum *a* to revolve, and the plough consequently begins to move forward. In returning, *d* will be the pulling rope and *c* the slack; and by another pitch-chain the drum *b* must drive the pinion *f* on the axis of the drum *a*, so as to gather up the rope *c*. In order, therefore, to disconnect the pinion *e* from the drum *b*, and to connect the pinion *f* with the drum *a*, ratchet-clutches are employed, and these are ingeniously regulated as follows. Each pinion is held in clutch with its respective drum by a spiral spring upon the axis; but by a simple movement the clutch is released by depressing the seat at that end upon which the ploughman rides to steer the implement. Thus when the plough is proceeding in the direction

of the arrow, and the workman seated, as at *g*, the pinion *f* is free, and the pinion *e* in gear for driving the drum *b* more rapidly than *a* is turned by the rope *c*, and the seat at the other end of the plough is in the position *h*. On the return journey the ploughman sits upon the seat *h*, throwing the pinion *e* out of gear, and allowing the pinion *f* to drop into gear by its spring-clutch. In order to show the principle of this implement clearly, many details have been omitted, and the exact proportion of parts has not been strictly preserved.

Fig. 4. Here suppose the rope proceeding from the plough to take one and a quarter turn round the first barrel of the windlass attached to the engine, and another one and a quarter turn round the second, before passing in a straight line to the anchorage at the other side of the field, embracing the large grooved wheel there, and finding its way to the back of the plough from which it started.

Fig. 5. *a* is the drum mounted beneath the boiler; *b* and b^2 are loose grooved wheels or sheaves placed on either side merely to lead the rope round. The rope *x* will be found to take a three-quarter turn round *a*, a half-turn round *b*, a half-turn round b^2, and another three-quarters turn round *a* before striking off at *s* to the anchorage at the other side of the field.

Fig. 7. The "clip drum" is here shown beneath the boiler of the engine, fitted with internal teeth, and driven by spindle and pinion which are perpendicular to it. The barrel beneath is to carry any odd lengths of rope. The construction of the drum is further shown by—

Fig. 8. Which represents a section. *a* and *b* are portions of the upper and lower flanges, which can be adjusted to different distances apart by bolts and nuts, as at *c*; *dd* represent a pair of the clipping pieces hinged on to the respective flanges; the rope *e* is taken between them, and by its even pressure inwards causes itself to be nipped.

THE BRITANNIA AND CONWAY TUBULAR BRIDGES.

BY WILLIAM CAWTHORNE UNWIN, B. SC.

THE Chester and Holyhead Railway, planned with a view to facilitate the journey from Dublin to London by shortening the sea voyage, is one of the most remarkable engineering achievements of this eminently mechanical age, whether we regard the importance of a safe and rapid communication between the capitals of this country and the sister isle, or the magnitude of the difficulties overcome in accomplishing it. And the bridges over the Conway River and the Menai Straits, the boldest of the works on the line, derive a special interest from the novelty of the scientific principles discovered and applied in their construction.

Three great names cluster about their history, names of men who had already achieved a foremost rank, each in his own department, and who, as they shared in the labour, must divide the honour of success. Robert Stephenson, the engineer of the line, had first to cope with the problem of constructing bridges of spans never before attempted in railway structures, and under embarrassing conditions imposed by the Lords of the Admiralty, to preserve unimpaired the navigation of the Straits. To him belongs the merit of the first conception and courageous carrying out of plans which were elaborated chiefly by Mr. William Fairbairn, to whom was intrusted an experimental investigation of the laws of resistance of wrought-iron structures. Harassed by parliamentary business in the exciting period of the railway mania of 1845-6, Mr. Stephenson had not the leisure to mature his own project, and Mr. Fairbairn himself, distrusting his power of dealing with the more refined mathematical questions involved in designing such unprecedented structures, called to his aid Professor Eaton Hodgkinson, who had long been associated with him in similar researches, but who, though able and enterprising, was more cautious and less confident of success than were his coadjutors.

I. *History of the Original Conception.*—Speaking roughly, we may divide bridges into three classes:—1st. Arched

Bridges, in which the vertically acting strain of the load is transmitted as a force of compression causing a divergent thrust on the abutments. 2nd. Suspension Bridges, in which the pressure of the load is transmitted as a tensile strain along two or more chains which exert a convergent pull on the abutments. 3rd. Beam or Girder Bridges, in which the pressure of the load is resolved within the structure itself into two horizontal forces,—one of compression acting along the upper portion, the other of tension along the lower portion of the beam. In this case there is no strain upon the abutments, except a simple vertical pressure equivalent to the load and weight of the structure.

Mr. Stephenson's first idea was to employ magnificent cast-iron arches of 350 feet span, which, in the case of the Menai Straits, he proposed to construct, by a most ingenious method, without the aid of centering. The boldness of the project may be understood when we recollect that the largest cast-iron bridges then erected were those at Southwark and Wearmouth, of 240 feet span. To this proposal, however, the Admiralty objected that the navigation of the Straits would be seriously obstructed. They demanded that any bridge there should have spans of 450 feet, with a clear opening of 103 feet above high water for the passage of vessels. Requisitions such as these, against which there was no appeal, would have vetoed the undertaking to any one less conversant with railway difficulties than Mr. Stephenson. He, however, at once reverted to the idea of adopting the *suspension* principle. He had, indeed, first of all contemplated the strengthening of Telford's fine suspension-bridge which crosses the Straits with one large span of 580 feet, to adapt it to railway purposes, a project very soon abandoned. But now in his perplexity he returned to his first plans. Such a bridge has a perfectly level soffit,* can be erected without centering, † and of all descriptionsof bridges, had alone, at that time, been employed in great spans. It has, in addition, the advantages of lightness and consequent cheapness; but, with the counterbalancing defect of extreme instability, arising from the unequal expansion of the chain and roadway, and even more seriously, from a tendency to vertical wave-like oscillations, with high winds or suddenly applied loads. Of these defects Mr. Stephenson was fully aware, having had not long before to replace a suspension-bridge on the Stockton and Darlington Railway, which had utterly failed from these causes, the rails having risen up three feet in front of the engine when the

* The underside of an overhanging structure.

† The wooden scaffolding or framing employed to support arches, &c., during their erection.

trains came upon it. Nevertheless, he thought that rigidity sufficient to prevent this might be introduced in the platform, whilst the bridge still derived its main support from the chains. "If the platform be made rigid, then I think the suspension principle may be applied." So he stated before the Parliamentary Committee in May, 1845. This stiffening of the platform had to some extent been already accomplished in America, and by Mr. Rendel, at Montrose, by means of *wooden trussing*. Their plans were considered, but rejected, and Mr. Stephenson's great merit consisted in choosing a better material and selecting a better form. The rigidity of *tubes* had long been known; he seized on the fact, and applied it to solve his problem,—"there was no way" he found, "so simple, so cheap, or so rigid, as throwing *iron-work* into the form of a tube."

The idea of a rigid suspension-bridge was both original and valuable. Probably it was rightly abandoned in the case of the Britannia Bridge, because neither the experience nor the experimental knowledge necessary for carrying it out were then attainable, yet attention is now again directed to it, and one of the most remarkable railway bridges in existence is that which Mr. Roebling has erected over the Falls of Niagara, of a span of 821 feet, and combining rigid iron girders and suspension-chains. Indeed, there are only two ways in which we can much exceed our present spans,—either by the introduction of a stronger material than wrought iron,* or by the adoption of the suspension principle under some modified form.

But even whilst giving his evidence in May, 1845, Mr. Stephenson was wavering in his adherence to this principle. Still believing the chains to be necessary in the erection of the bridges and advisable as a permanent precautionary measure, he had begun to think of throwing the chief part of the strength of the bridge into the tube itself. Having abandoned the principle of the arch, he was faltering in his attachment to that of suspension, and was progressing towards the adoption of that of the simple beam or girder. This change in his views he attributes three times in the course of his parliamentary evidence to information supplied by Mr. Fairbairn, whom he had called to his aid about a month before.

Mr. Fairbairn had been engaged in iron-ship building, and had known cases in which iron vessels of 250 feet in length had been stranded at the extremities and left suspended, precisely in the condition of a bridge, with 1,000 to 1,200 tons of machinery in the middle, yet without injury. Relying on these

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* Attempts have already been made to introduce milled steel for this purpose; and there is great probability of its being ultimately adopted when, by the new processes of manufacture, its price is sufficiently reduced.

facts, and having always had an antipathy to all forms of trussed beams, Mr. Fairbairn appears to have believed from the first that a simple tubular girder, without auxiliary chains, but of the form first suggested by Mr. Stephenson, would best meet all the requirements of the case. In this opinion neither Mr. Stephenson nor Mr. Hodgkinson concurred till a much later period; the former was determined "to have two strings to his bow" (both chain and girder), and the latter was sceptical as to the resistance of the tubes to compression. It is a curious fact in proof of this, that the Conway Towers, commenced as late as May, 1846, were built with the necessary provisions for the reception of the chains as originally designed.

II. *The experimental Inquiry.*—The general principles of girder bridges were already ascertained; the form of greatest strength in cast-iron had been determined by Mr. Hodgkinson; but of wrought iron much less was known. The strength and proper distribution of this material was, therefore, the subject which Mr. Fairbairn set himself to investigate in a series of experiments. He at once proceeded (July 1845), abandoning all reference to suspension-chains, to test the actual resisting powers and mode of fracture of various kinds of tubes. Cylindrical tubes, as the simplest, were first tested; then elliptical tubes, specially recommended by Mr. Stephenson; and lastly, rectangular tubes. The rectangular tubes were found to be decidedly the strongest, next to these the elliptical, and weakest the cylindrical. Thus the first of the distinctive principles of the bridges—the *rectangular form,* was at once deduced from the experiments; and the other was soon to follow. Almost all the tubes had given way by the crumpling or buckling of the upper part, as shown in Pl. XXIII., fig. 3. The resistance of thin plates to compression was evidently very inferior to their resistance to tension. It was necessary to strengthen the top, and this Mr. Fairbairn effected by means of a *cellular fin.* A tube was constructed of an ellipitical form and with a triangular cell at the top (Pl. XXIII., fig. 1), and the result was so satisfactory that a rectangular tube with two cylindrical corrugations or cells was at once planned (fig. 2). This tube (which obtained the name of the spectacle tube) was experimented upon October 14, 1845, and first combined the two novel features of the bridges. From this period every difficulty in the design of the bridges disappeared.

In March, 1846, the first definite calculations of the areas of metal in the Conway tubes were made, and a model was constructed of 1-6th the real dimensions, which was submitted to experiment with a gradual increase of area in the bottom until the resistances to tension and compression were precisely

balanced. These experiments finally determined the proportions of the bridges. The progress achieved by the experiments is shown by the following figures.

Comparative Strength of Tubes of the same weight, depth, and span.

Cylindrical	13·0
Elliptical	15·3
Rectangular	21·5
Model tube with cells	26·7

That is, the strength of the cylindrical tubes was more than doubled, with a better distribution of material in a rectangular form and with a cellular top.

III. *The General Form of the Bridges.*—The bridges ultimately erected consist of huge tubes or tunnels of wrought iron, spanning the water horizontally from pier to pier, and carrying a single line of rails within each, as shown in Plate XXIII., fig. 4, which is an elevation of the Britannia Bridge, and in fig. 5, which is a section across one tube at the centre. They are composed of rolled plates with longitudinal L iron bars, in each of the corners, and vertical T iron pillars or struts* to stiffen the sides, the whole being united by riveting. This construction will be explained by fig. 6, which is a section at one corner of the tube (fig. 5) on an enlarged scale. No auxiliary chains were used in the erection of the bridges, part of the tubes being built on scaffolding and the remainder on stages on the shore, whence, when completed, they were floated into their proper position and raised by Bramah presses.

The Conway Bridge has a single span of 400 feet, crossing the river close under the walls of Conway Castle, at a height of only seventeen feet above high water. Each of the tubes weighs 1,200 tons.

The Britannia Bridge is a much larger structure, having four spans, an elevation of which is shown in Plate XXIII., fig. 4. The entire length of each tube is 1,511 feet, and the length of the bridge, inclusive of the abutments, 1,841 feet, or more than a third of a mile. At the point selected for the bridge, the Britannia rock, uncovered at low water, divides the straits into two approximately equal portions (see fig. 4), on this the central, or Britannia Tower, was erected. On either side, at a distance of 460 feet clear span, two smaller towers were constructed on the strand; and again, at 230 feet distance from these, the Anglesea and Carnarvon abutments, each 176 feet in length. The towers are of very simple but massive form, suiting the simple outline of the stupendous structure they sustain. The Britannia Tower is 221 feet in height and 50 feet by 60 feet at the base. It contains 25,000 tons of

* The parts of a framed structure under compression.

THE BRITANNIA BRIDGE.

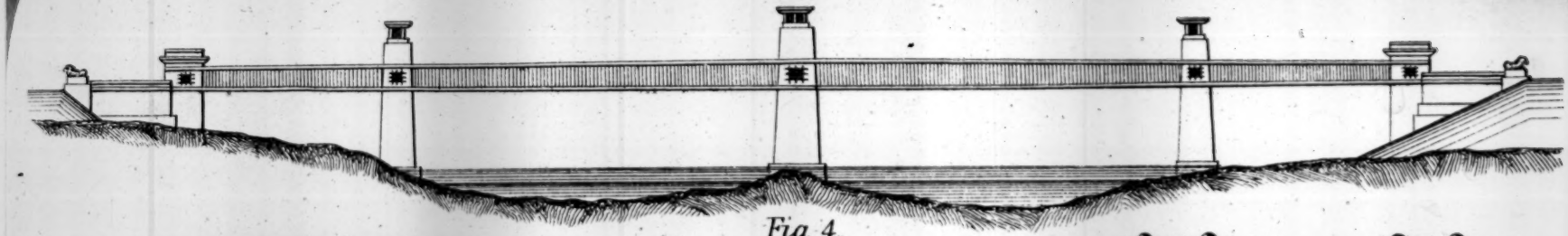

Fig. 4.

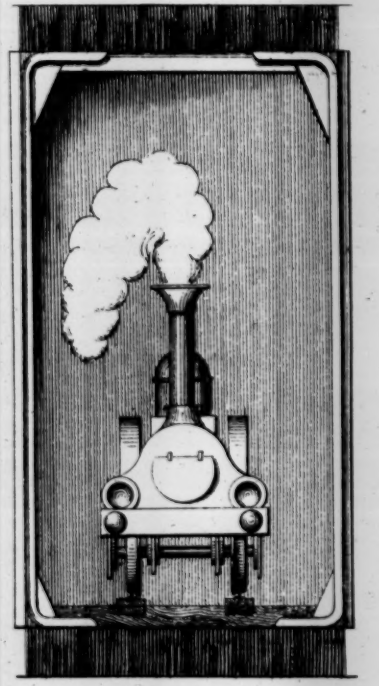

Fig. 5.

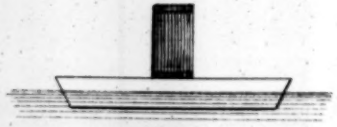

Fig. 7.

Fig. 3.

Fig. 1.

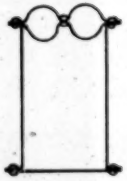

Fig. 2.

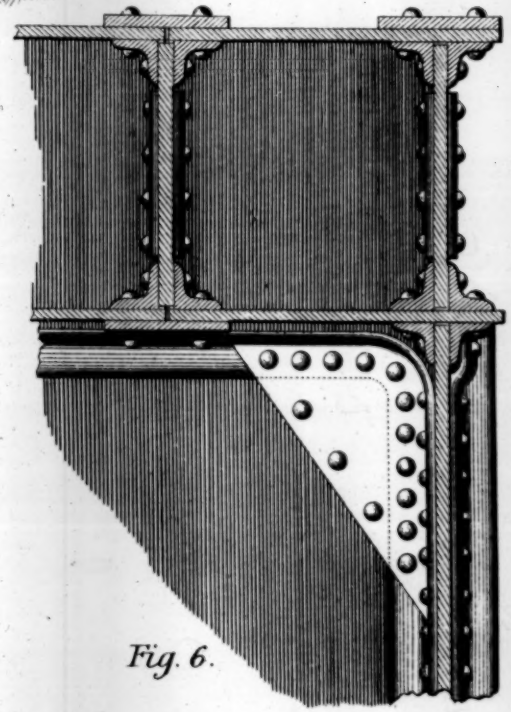

Fig. 6.

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masonry and brickwork, and 479 tons of iron built in. The side towers are almost as large, rising 177½ feet from the plinth. The abutments each 176 feet in length are 87½ feet in height on the Carnarvon side, and 143 on the Anglesea side. They are terminated by projecting pedestals, on which are placed colossal couchant lions, weighing 30 tons. The entire amount of masonry in the bridge is one million and a half of cubic feet or 100,000 tons, which it is calculated was built up continuously for twelve hours a day, at the rate of three cubic feet per minute.

The two tubes are now continuous over all the spans, the greatest depth being thirty feet in the Britannia tower, tapering down in a parabolic curve to twenty-three feet at the ends. The large sections for the spans of 460 feet have eight cells at the top and six at the bottom, as shown in section, Plate XXIII, fig. 5. The general dimensions are as follows :—

	Weight. Tons.	Sectional area in centre. Square inches.
Top	1481	648·25
Sides	1727	302·00
Bottom	1472	585·43

The two tubes in their present state, 1511 feet in length, contain, 9360 tons of wrought iron, 1015 of cast iron, and 165 tons of permanent way. They are estimated to have been constructed of 186,000 separate plates and bars united by upwards of two millions of rivets.

In so great a length of iron the effects of change of temperature on the length of the tube is very considerable. In fact, taking the extreme variation of temperature in our climate to be — 5° and + 115° Fahr., or to range over 120°, the variation of the length of the tube would amount to fifteen inches.

To provide for this the tubes are firmly fixed on immoveable bed-plates within the Britannia tower, whilst above they are also attached to suspension-bars firmly connected with the masonry. But in the side towers and abutments they are free to move longitudinally on an arrangement of cast-iron rollers. Above there are suspension rods, which are attached to girders, also rolling freely on gun-metal balls. With these arrangements the tube is in unceasing motion, the diurnal variation of length amounting to from half an inch to three inches.

Another curious effect is that resulting from the unequal heating of the sides of the tubes. They become convex towards the sun from the elongation of the warmer side. Hence, as the sun moves across the zenith they revolve in a plane at right angles to their length in an irregular curve which varies with the weather, and shows the effect of the slightest irregularities of temperature—from passing clouds, for example.

To break one of the girders of the Britannia Bridge would require about 5200 tons distributed uniformly over the 460 feet span, including the weight of the tube. The weight of the tube is 1550 tons, and the weight of a train of the most heavily laden trucks, extending over the entire span, would be about 570 tons. If we deduct the weight of the bridge from the breaking weight we have a surplus strength of 3650 tons to resist the rolling loads, or the proportion of six and a half to one, nearly. Or according to another method of calculating the strength, for the authorities differ at present as to the proper plan, 1550 + 570 = 2120 tons, which must be considered as the maximum load which can be brought on the bridge. The strength will then be nearly two and a half times the maximum load.* The deflection of one of the Conway girders from its own weight was nine inches in the middle; that of the larger Britannia girders twelve inches.

IV. *The Construction of the Tubes.*—The tubes for the Conway Bridge were constructed on a platform on the beach of the river, 420 feet long by 40 wide, workshops containing shearing, punching, and riveting machines, with furnaces and forges, being erected on the land close by. The plates as they were wanted were straightened by a hideously noisy process of hammering on massive cast-iron bed-plates, or by the quieter process of passing through rolls. They were then sheared to the exact size, and the positions of the rivet holes marked ready for punching. The ordinary punching machines have one, two, or three punches which rise and descend with a slow reciprocating motion of about four strokes a minute, and they have dies of the same size beneath. The workman adjusts the plate with great dexterity between the punch and die, so that at each descent of the former a hole is made in the required position. This is effected with the greatest ease, although forty tons pressure is necessary to punch a hole of ordinary size in a three-quarter inch plate. A very remarkable self-acting punching machine, by Mr. Roberts, was partially employed for the Britannia Bridge. It worked on the principle of the Jacquard loom, and punched any pattern of holes across the whole width of the plate without previous marking, the plate being carried forward on a sliding table. The importance of the operation may be judged from the fact that, according to Mr. Clark's calculations, there are seven millions of holes in the Britannia Bridge alone. The plate when punched was removed to the erecting platform, and carried by means of a travelling crane, moveable, over the whole extent of the stage, to the position it was to occupy in the girder.

* The effect of the continuity of the girders in strengthening the bridge has, however, been neglected in these calculations.

The annexed figures illustrate the nature of the riveted joints of the bridges. Fig. 1 is a rivet with one head formed ready for use. This is put through two corresponding holes in the plates to be united, and a second head formed by hammering. A section of such a joint is shown in fig. 2.

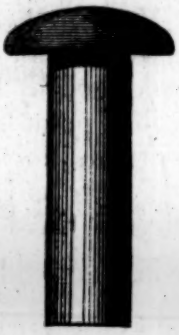


Fig. 1.

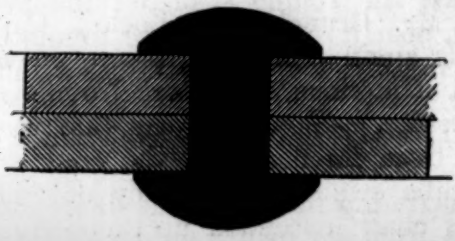


Fig. 2.

In the Britannia Bridge the four land-tubes were erected in their permanent position on scaffolding of great strength. The four larger tubes, each 472 feet long, were built on the Carnarvon shore of the straits, on similar stages to those employed at Conway; workshops adjoined to them on the land, and behind these were cottages for 500 workmen.

V. *Floating and Elevation of the Tubes.*—We have seen that the original intention of throwing suspension chains across the straits to form a platform on which to erect the girders was abandoned. A simpler, less expensive, and more efficient plan was devised, that, namely, of building them on the shore, where pontoons could be brought beneath them at low water, so as to float them with the rising of the tide; thence to guide them safely about 500 yards as they were impelled by the current, and to drop them, as the tide again fell, on masonry shelves at the bottom of the towers. A description of the manner in which this was effected for one of the main Britannia girders will suffice for all. The preliminary arrangements comprised the attachment of two huge twelve-inch hempen cables near the tube, and extending them across the straits to capstans on the Anglesea shore. These guide-cables passed through hawse-holes in the outermost pontoons, and guided the ends of the tube. Immensely powerful friction-breaks were placed in the pontoons on each of these guide-cables, by which the motion of the tube could be retarded in any required degree, as it was feared that, left to the current, it would become unmanageable. To haul the tube out of its position in-shore two eight-inch cables were extended across the straits from moorings on the Anglesea shore to capstans on the pontoons. Lastly, four other capstans were placed

along the shores with cables moored out into the stream; these were taken up in turn as the tube reached them and served for adjusting it to its resting-place in the towers. Thus prepared, with the aid of Captain Claxton and a large body of sailors, the operation of removal was commenced. An ineffectual attempt was made with the first tube on the evening of June 19, 1849. Next evening Mr. Stephenson, with Mr. Brunel, Mr. Locke, Captain Claxton, and some friends again took their places on the tube, watched by thousands of anxious spectators from every accessible point along the banks. Slowly as the tide rose the pontoons took the tube from its bearings, the land attachments were cut, and the tube swung majestically out into the stream, held by a radius chain extended up the shore. This was cut, and the tube slid slowly down the great guide cables, Mr. Locke and Mr. Brunel assiduously watching the application of the friction breaks, whilst from the top Mr. Stephenson signalled by flags to the various capstans on shore. As the buoyed ends of the other cables were reached they were attached; the tube was brought up against a butt near the Anglesea tower, and on this, as a fulcrum, swung round to its position at the Britannia tower. It was hauled home here, and the other end glided into its place. Gradually, as the tide fell, the pontoons left their stupendous cargo safely resting on the bases of the towers.

The tubes weighing 1,550 tons had now to be raised to a height of 100 feet. This was effected by three enormous Bramah presses,* placed at the top of the towers and worked by steam-engines. Massive flat-linked chains were suspended from the cross-heads of the presses in the towers, and attached to the ends of the tubes; each link six feet long had a square shoulder by which it was attached to the cross-head by clips. As the

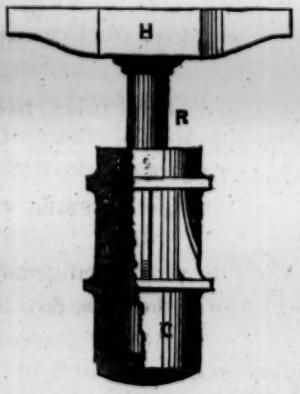


Fig. 3.

* The hydraulic press improved and introduced into general use by Bramah acts upon a principle long understood, the application of which in the production of great pressure was suggested by Pascal in the middle of the seventeenth century. It consists of a cylinder, C, into which water is pumped at a considerable pressure, either by hand, or, as in the case of the bridges, by steam-engines. In the cylinder is a solid ram, R, sliding freely through a peculiar water-tight joint at the top, the invention of which is due to Bramah. H is the crosshead from which the chains were suspended. The water is pumped in through a small pipe (not shown) at a pressure of about three

water was pumped in, the ram rose through its stroke of six feet, lifting the tube to that extent. The chain was then gripped by a second series of clips on the massive beams beneath the press; the ram was finally allowed to fall, and having grasped the chain six feet lower, began a new stroke. The tower was built up beneath the tube as the raising was effected. Thus, by slow stages, between the middle of August and October, the first tube was raised to its place. Delay having been caused by the failure of one of the presses, an accident which threatened the destruction of the tube. The other tubes followed. The last was floated July 25, 1850;—the first stone of the bridge having been laid September 21, 1846. Thus ends our brief account of the design, construction, and erection of these bridges, and although we can hardly hope that all the technical details of the subject have been clearly explained to our readers, yet we trust that we have imparted to even the most popular inquirer some idea of the great difficulties which have been overcome, and of the wonderful work which has been achieved in the completion of a magnificent work of engineering skill, which is the pride of every Englishman, and elicits the admiration of every foreigner who visits our shores.

tons per square inch. The area of the ram in one of the Britannia presses was 270 square inches, and the lifting power about $270 \times 3 = 810$ tons.

In order to pump in the water two forty-horse power steam-engines were employed, working pumps $\frac{1}{10}$ inch diameter. The area of each pump piston was, therefore, 0·886 square inch, and the pressure against this at three tons per square inch 2·6 tons; it was against this resistance only that the power of the engine was exerted in producing a lifting pressure in the press of 800 tons.

Fig. 3 represents an hydraulic press, partly in section, partly in elevation.

EXPLANATION OF PLATE XXIII.

Fig. 1. The elliptical tube with a fin, or first cellular experimental tube.

2. Rectangular experimental tube, with two cells at the top, familiarly known as the "spectacle tube."

3. Side view of fractured part of one of the experimental tubes, to show the nature of "buckling," or yielding to compression.

4. Elevation of Britannia Bridge. Scale about 1-3210th.

5. Cross section through the middle of one of the Britannia tubes, showing cells, &c. Scale about 1-124th.

6. Upper corner of fig. 5, on a larger scale, showing arrangement of plates, angle iron, and covering strips, to form the cells, &c. Scale about 1-15th.

7. End view of one of the tubes resting on the pontoons.

PRIMITIVE ASTRONOMY.

BY THE EDITOR.

"THIS is a fine, clear night, sir; is it not?"

"Indeed it is: and how brightly that star shines above all the rest."

"It does; pray what star may that be, sir?"

"Why, it is called Jupiter: correctly speaking, it is not a star; but I dare say you know as well as I do that it is a world like the one on which we live."

"A world, sir! No! *Then have navigators really got as far as that?*"

This is no imaginary dialogue; the speakers were a Liverpool cab-driver and the writer of these lines.

Three or four hours' confinement in a crowded saloon had induced us to seek the cool evening air, on our return home from a place of public entertainment; and leaving our companions to occupy the inside of the vehicle, we selected the less dignified but more airy seat beside the driver, and were accordingly favoured with an excellent opportunity, had we been so disposed, to deliver a popular lecture on astronomy to a limited, but attentive and inquiring auditory!

The refreshing breeze from the Atlantic, and the cloudless, starlight night, had not, however, operated in this direction; they had so raised our spirits, that when the last exclamation escaped from our companion, our first impulse was to laugh outright at the absurdity; but an instant's reflection showed us that such a state of ignorance, even in an uneducated cab-driver, should rather move to pity than to merriment; and we endeavoured, as well as we were able, to make our companion understand, that it is impossible for human beings to breathe and live beyond the limits of our atmosphere, and that our knowledge of the nature and position of the star which shone so brightly in the heavens, was the result of reasoning, aided by the employment of philosophical instruments.

But what a deplorable illustration did this man present of the ignorance still existing in this our boasted land and day of enlightenment, when "Working Men's Institutes" are the

fashion, and the lord lectures to the labourer! Here was a citizen of the most important seaport in the world; one who in all probability had an indirect voice in the government of the country; who may have attended divine worship regularly, and have formed some idea of the nature of the Godhead; ay, for all we know, he may have been and may still be a zealous member of some "Cabmen's Missionary Society," actively employed in the task of converting sinners; and yet this man was almost as ignorant of the true character of the natural world by which he is surrounded as the poor dumb brute that he lashed with the whip or encouraged to proceed with a clack of his tongue.

Why, if those Chaldean shepherds of old, who are said to have been the Fathers of astronomy, and whose occupations are to some degree analogous to those of our cab-driver; if these had possessed half his advantages, had been acquainted with the use of electric telegraphs and railways, and been able to learn all that was known in their day through the medium of the printing press, for the cost of a draught of their wine, they would have far exceeded this man in intelligence! And yet it is thousands of years since these poor shepherds watched the sun in his annual and diurnal course, marked his progress in the heavens, and, with him for a teacher, learnt how to divide the year into its due times and seasons. And the ignorance of the old astronomers, even those of Heathendom, was edifying beside that of the uncultivated minds which cast such a shade over the brightening intelligence of our Christian era. *Their* erroneous notions were at least poetical, and bore the mark of some kind of religion, whilst in our day this absence, in an adult, of the veriest rudiments of education is only suggestive of debased habits, and physical as well as moral depravity and destitution.

Take, for example, the primitive theories concerning the Sun's nature.

The ancients were not content to receive his warmth and light; caring nothing as to whence he came, or whither he went, as do the ignorant of to-day, to whom life is but a season of sensual enjoyment.

No, they strewed his path in the heavens with the flowers of poesy and sentiment.

Even whilst the earth was still regarded as a flattened plain, bounded on all sides by the ocean, the heavenly bodies were believed to emerge from the latter at their rising, and again to sink into its depths at their setting.* The Iberians believed that they heard the hissing of the water when the burning Sun plunged into the Western Ocean.

* Lewis. "Astronomy of the Ancients." 6, *et seq.*

"The Greeks even conceived the Sun in the personified form of a divine charioteer who drove his fiery steeds over the steep heaven until he bathed them at evening in the western wave."

Nor were these observations, which at first served only to impart some reality to the Mythology of the Ancients, useless in their subsequent results.

The question naturally arose: If the Sun emerged from the Eastern side of the world, and descended under the Western horizon, where was it during the hours of darkness?

Gradually the researches of one astronomer, and of one school of astronomers after another, led to the conclusion that it passed *underneath* the Earth, and revolved round it along with all the other heavenly bodies. The Earth was, therefore, constituted the centre of the Universe. This step in astronomical knowledge being accomplished, other discoveries succeeded. The rotundity of the Earth, the unequal motion of the Sun, the Earth's motion, the central position of the Sun, and the nature of the planets and fixed stars, were all revealed one by one, until the harmonious moving Solar system assumed the place of the flat, immovable Earth with its crystal vault of Heaven wherein were set, like so many sparkling jewels, those myriads of stars to which "navigators" could not penetrate.

Let us endeavour, in the few pages at our disposal, to trace the first efforts by which the human mind was emancipated from the thraldom of ignorance, and which subsequently led to the acquisition of a knowledge of the actual nature of the Solar system, and of so much of the universe as has been revealed by the telescope.

It is hardly necessary to explain why the ancients believed the Earth to be a flat plain. With the exception of its hills and valleys it appeared so to the naked eye, and its inhabitants had neither instruments wherewith to observe their receding or approaching barks on the ocean,* nor were their vessels of such a character as to admit of the complete circumnavigation of the globe. They consequently judged of the Earth's form, for a length of time, by the evidence of their senses only, holding it to be a circular plain surrounded on all sides by water upon which it floated; and the firmament above was regarded as a solid vault, various astronomers attributing to it a different composition.

Some, for example, conceived it to be a "fiery ether;"

* Doubtless most of our readers are well aware that one of the proofs of the Earth's rotundity is found in the fact that the masts of vessels are the last portions which disappear below, and the first of which appear above the visible horizon.

others, that "the extreme part of the heavenly sphere is earthy and solid;" and others, again, imagined that the blue sky consisted of "air condensed by fire so as to assume the substance of ice." This firmament was supposed to revolve around the Earth, and the stars were believed to be attached to it, *their* nature again being the subject of much consideration and discussion. According to some of the Greek astronomers they were "circular bodies of condensed air containing fire," whilst others regarded them as "compressed fire fed by exhalations from the Earth," and others, again, as "stones ignited by the fiery firmament."

The last theory was propounded by Anaxagoras, a Greek philosopher, who probably entertained this idea from the examination of aërolites, of which one of large dimensions fell during his lifetime (about the year 468 B.C.), in Thrace.

His views concerning the heavenly bodies generally were rather more rational than those previously adopted, and in some cases he arrived at conclusions which have been confirmed by the revelations of modern science.

Whilst, for example, one observer compared the Sun to a wheel, of which the spokes were the rays, and another likened it to a "bowl or hollow hemisphere" (a solar eclipse taking place when the luminous convexity is turned upwards and the dark concavity towards the Earth), this bowl being no larger than the Sun really appears to the naked eye, namely, about the width of a man's foot;—whilst, we say, these were the extraordinary notions entertained by some philosophers concerning the orb of day, Anaxagoras had arrived at the conclusion that the sun is a mass of ignited stone, and his ideas of its size were also somewhat advanced, for he believed it to be "larger than the Peloponnese." But what is more remarkable, he believed the Moon to be an "Earth having its plains, mountains, and valleys, and likewise its inhabitants." He considered that it derived its light from the Sun; arrived at correct conclusions as to the cause of eclipses of the Moon, believing them to be due to the interposition of the earth between the Sun and Moon, and on all subjects he wrote with "boldness and freedom."*

The reader will not be much surprised to hear that as a result of this enlightenment he was persecuted by the adherents of the established religion; compelled to move from city to city; was accused of impiety, imprisoned, fined, and that he at length emigrated. He died at the age of seventy, about 430 B.C.

Anaxagoras not only wrote on astronomy, but also on the

* These quotations concerning the astronomical theories of the ancients are from Sir G. C. Lewis's work.

mythology of his people, exposing its fallacies and the allegorical character of the gods. This, no doubt, drew upon him the animosity of the orthodox of that day, more than did his physical discoveries; for we find that in every age the revelations of science have had the simultaneous effect of dispelling the clouds of ignorance and superstition.

But we must retrace our steps and return to the earliest astronomical discoveries.

We find that, at all times in the history of our race, the most important advances in knowledge have been, more or less, directly associated with the physical requirements of the people by whom they were made; and in no phase of human intelligence is this so manifest as in that which relates to the progress of astronomical knowledge.*

Let us for a moment suppose a completely untutored race of human beings placed in some tolerably fertile region of the globe, with purely animal wants and instincts, and with the capacity of adapting themselves to surrounding circumstances. These lowly wants would alone compel them to direct their attention to astronomical occurrences.

At first the natural and spontaneous productions of the soil suffice for their sustenance. Fruits, esculent roots, and the flesh of animals not only afford them nourishment, but even minister to their taste for luxuries. As evening approaches they find themselves weary and lie down to rest, and with each returning morn comes the renewed strength which Providence infuses during sleep, and which prepares for the labours and pleasures of the coming day.

But such a people as we are describing soon discovers that trees do not always bear fruits, that game is not always found in plenty, and that when plants appear to die, the animals which feed on them, and which in their turn serve the human inhabitants as food, retire to their haunts to seek shelter from the inclement season.

The human denizens, however, continue to multiply in winter as in summer, in rain as in sunshine, and a store of food must therefore be laid up for their little ones as well as themselves, or they would perish.

Their earliest observations, prompted by their lowest animal feelings and appetites, cause them to perceive that whenever they are most in need of food and warmth the Sun is low—that then it possesses but little power—whilst, when their trees and shrubs are producing fruit, and food is plentiful, he stands high

* The publication of the "Nautical Almanack" by the first maritime nation in the world, has, perhaps, prompted a more diligent scrutiny of the heavens than any other circumstance in the history of our race.

in the heavens and emits his most powerful rays.* Their first impulse is naturally to regard him as a deity.

And so it was in ancient times; the Sun was worshipped as the giver of light and warmth, and of all the richest fruits of the earth; and his movements in the heavens were closely watched in order to obtain some clue with regard to his true nature.

But in addition to this power of observation which our race possesses, another attribute of reason is that which prompts us to *record* impressions made upon the mind with a view to guide our contemporaries and posterity. This is a characteristic in the mental nature of man which serves as a marked distinction between him and the lower animals, and constitutes the difference between his education and theirs.

The ant and the bee convey information to their congeners of the discovery of a store of provender; the cat can teach its kitten, and has even been known to instruct a young dog in the art of begging† (the most striking example of educability in the lower animals that we have seen recorded); but in these and similar cases the capacity is limited to the individual and never extends to the race. Should all the parent bees or ants die, or be removed before the young ones are born, no record will have been left to them of the experience of their progenitors, and the store or booty must be rediscovered, by accident or instinct, before it can become available for their use.

Not so with man. The traces of his active mind and restless enterprise are everywhere to be encountered: in history, the arts, ancient relics, and works of engineering industry; and the records of many of his earliest impressions still serve us as guides in every-day life. No illustration of this is more striking than the sun-dial, one of the earliest devices of man for regulating his physical and mental operations, and at the same time an index to some of the earliest manifestations of his mental development; and yet this primitive chronometer is still in use, on the walls of village churches, as well as on the lawns of the affluent.

When our ancestors watched the daily progress of the Sun through the sky, they perceived that, as he rose towards the zenith, the shadows which he cast on the ground became shorter, whilst, as he descended towards the horizon, they increased in length; and they also noticed that there were certain periods or seasons when his shortest, or what we term his noon-day

* Some of the ancient nations had only three seasons instead of four as in our day. The most striking changes in nature took place in Spring, Summer, and Winter, and these were the subdivisions of the year. Autumn or Harvest ("Herbst" of the Germans), was a later introduction.

† Jesse. "Popular Science Review," No. I., p. 118.

shadow was longer than it was at other periods. In order to record these phenomena, and the better to trace their cause, they simply set up a pole in the ground, and marked the length of its shadow at regular intervals.*

They soon found that the noon-day shadow increased in length day by day until it attained a certain measurement, and that then it remained unchanged for a few days; after this it as regularly decreased until it arrived at its shortest dimensions, and then again stood still for a while before resuming its diurnal increase.

The period when it was the shortest was called the summer "solstice;" the Sun then "stood still," high in the heavens, and its heat was the greatest. The longest noon-day shadow constituted the winter "solstice," and the duration from either of these phenomena to its recurrence was *a year*.

It was found also that about midway between these periods (the summer and winter solstices) there were two others, when the day and night were equal, and these two periods were known as the equinoxes, all these terms being still employed by astronomers.

In like manner did the ancients measure off the gnomon's shadow from the Sun's rising until his setting, and employ it to denote the time of the day. Thus, we are informed that "a person was invited to dinner by asking him to come when the shadow of the gnomon was so many feet long;" and, as in our day, we have a "Greenwich time" for our clocks, so are our ancestors said to have had a standard measure by which their gnomons were regulated.

The changes referred to, in the relative position of the Sun and Earth, offer no problem to our modern astronomers, who know that these appearances are due to the annual revolution of the Earth round the Sun, and the daily rotation of the former on its own axis.

But to the dawning intellect of the shepherd astronomer the consideration of these phenomena was fraught with many difficulties, for he believed the firmament to be a solid sphere in which the heavenly bodies were firmly set, and with which they, therefore, revolved around the Earth as a centre. How, then, could the Sun deviate from its regular course, now rising and setting in one part of the heavens and now in another, whilst the constellations (for, from the earliest ages, the fixed stars were mapped out in groups) always maintained the same relative position in the firmament, rising and setting

* In common with many astronomical discoveries, the earliest application of the sun-dial (or "gnomon"), is buried in obscurity. It is supposed to have been invented by the Babylonians.

one day as another, and showing no perceptible change in their movements.

Nor was his perplexity diminished when he found that what applied to the Sun was still more strikingly manifested in the movements of the Moon, for not alone did her course in the heavens vary from day to day, but with it her very appearance became changed.

Sometimes he found her highest daily altitude to be less than that of the Sun in the depth of winter, whilst at others it was even greater than that of the same luminary at midsummer. Again, at one time, the Moon appeared to be advancing towards the Sun in the heavens, and at another to be receding from the position which he occupied; whilst, strange to say, the nearer she approached him the less luminous she became, assuming at length the form of a thin bright crescent, whilst, with increased distance, came greater brilliancy; and, as she receded from the Sun, the crescent gradually expanded into a broad circular luminous disc, which almost sufficed to convert night into day.

But another and a still more surprising phenomenon was soon revealed to the wondering gaze of the early student of the heavens. Even the stars themselves did not appear in every case to be fixed in the celestial vault, and one bright wanderer* after another seemed to start from his fixed home in the heavens and slowly to mimic the movements of the great luminaries of day and night, until no less than five had been discovered who refused to be held by the inflexible bond that fettered all the rest.

Judging from their degrees of brilliancy and the comparative changes of position to which they are subject, modern astronomers are disposed to believe that first Venus, next Jupiter, then, consecutively, Mars, Saturn, and Mercury attracted the attention of the star-gazers of ancient days; and it was soon discovered that two of these planets—Mercury and Venus—were nearer to the Sun than is our Earth, and that they actually passed behind it and revolved round that luminary.†

How great must have been the perplexity of our ancestors as, one by one, these abnormal and apparently contradictory phenomena forced themselves upon their observation! How troubled they must have been to account for these apparent changes in the regular order of nature as conceived by their predecessors and themselves!

The Sun, indeed, revolved round the Earth at regular inter-

* Hence called "Planets," from a Greek word signifying to wander.

† The ancient Egyptians were well aware of this fact. See "Chambers's Handbook of Astronomy," diagram on p. 25.

vals, as did also the Moon, the planets, and the stars; but, then, how could they be fixed in one revolving dome, when the orbits of the two former were elevated or depressed at various seasons and periods of the year? the Sun requiring a year, and the Moon about twenty-nine days to complete its cycle; five of the stars wandering without any apparent order, but all the rest fixed and immovable, as if to silence the doubts of the heterodox, and to confound the calculations of ingenious speculators. But to give a final blow to the theory of the Earth's central position and the one revolving firmament, it was discovered, after a lapse of many centuries of careful observation, that the Sun's path in the sky was gradually changing, to speak familiarly; that it did not rise and set with the same stars at the same period every year, but was gradually moving towards the west, leaving the fixed stars behind it.*

Many and ingenious were the theories by which the apparently eccentric motions of the heavenly bodies were sought to be explained. The circumstances to which we have referred, and the discovery of the true nature of eclipses, rendered the theory of one single solid firmament equi-distant in every part from the central Earth around which it revolved, quite untenable; and the first important step in ancient cosmogony was that which divided the crystalline vault of heaven into belts or zones more or less distant from the Earth; each belt containing its own section of the heavenly host.

The Moon was known to be nearer to the Earth than the Sun, for her dark body was found to interpose between these two spheres, and she therefore was placed in the nearest zone: next came the zones of the Sun, planets, and fixed stars respectively, each making its own appropriate revolution.

This theory met one difficulty, namely, the variable distances of the different heavenly bodies from the Earth, and even to some extent, the regular elevation and depression of their orbits; but it was not sufficient to account for the slow changes which took place in the latter, and to explain this phenomenon, Pythagoras† supposed a motion in the Earth itself, and removed it from its central position in the Universe. His cosmical system was, however, very vague, and was made up of a strange compound of fiction and fact. Such as it was, however, it maintained its position until the true nature of the Solar system was revealed 2,000 years subsequently by Copernicus, the great Polish astronomer.

We shall now present to our readers the Pythagorean system, as enunciated by his followers, in contrast with the earliest

* The precession of the Equinoxes. See any Handbook of Astronomy.

† About 500 years B.C.

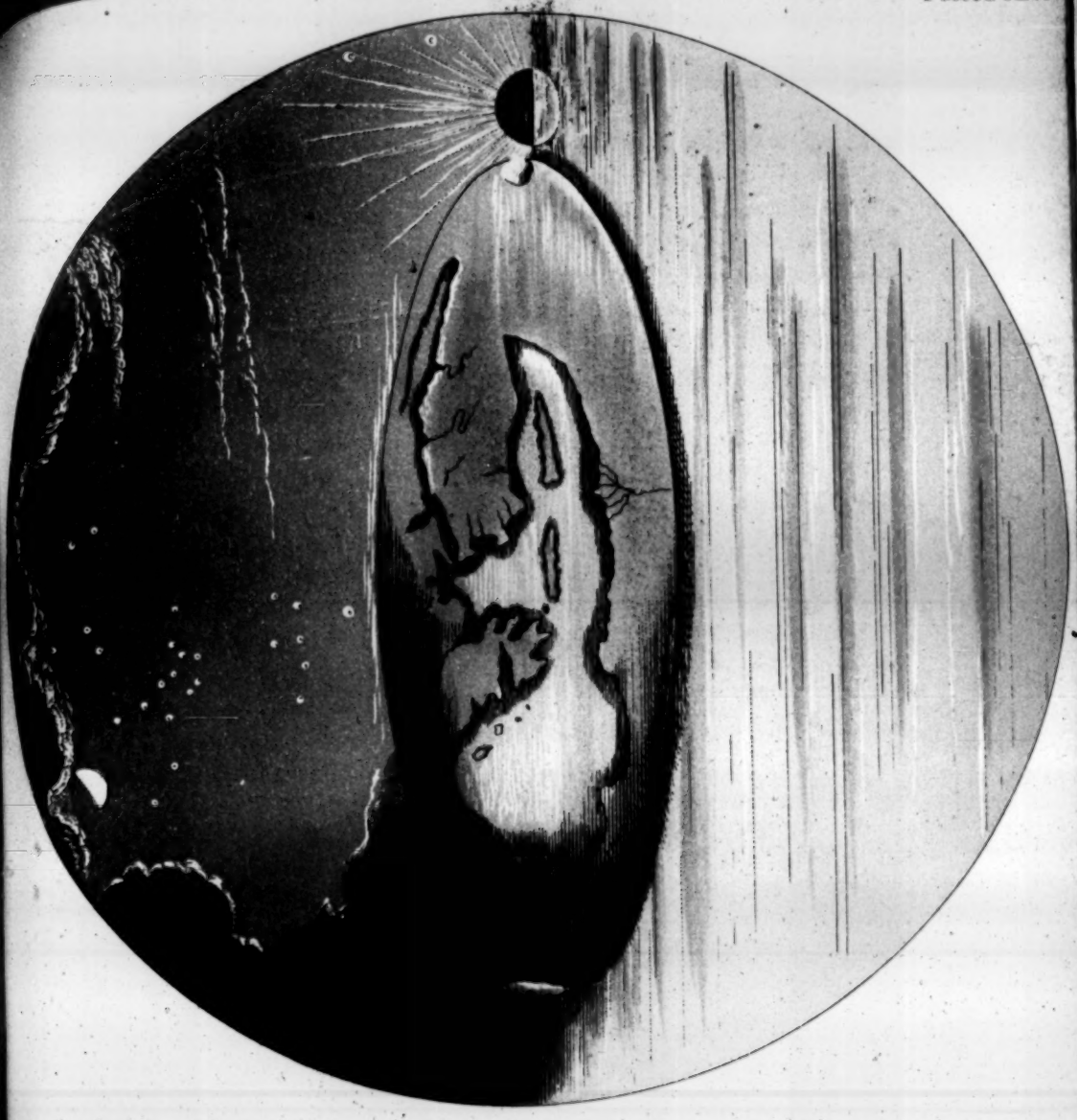
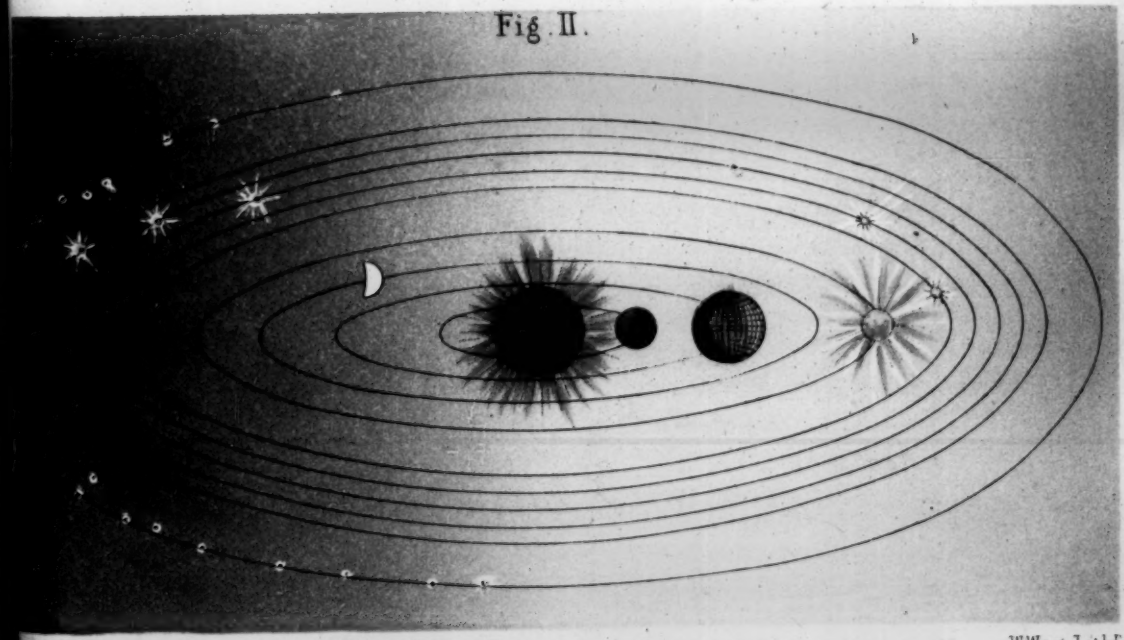


Fig. II.



received ideas on the same subject, and shall then be compelled to draw these observations to a close.

For this purpose we would direct the attention of our readers to the accompanying plate, in which the first figure represents the Universe, as it was believed to be constituted in the time of Homer; and the second (which is based upon the exposition of the Philolaic system, published by Professor Aug. Bœckh, of Heidelberg, in 1810) is an ideal view of the same, according to Pythagoras and his school.

In the first figure we have the world, according to Homer, a flat circular body, floating upon the ocean by which it is surrounded. In the east is the sun, rising from his "Lake,"* to pursue his daily round, and tinting the plains of western Palestine with the rosy hue of morning.

In the west, darkness still reigns over the land. The Moon and stars, firmly set in the crystal dome of Heaven, cast their silvery light upon the Adriatic Sea, and on the island of Thrinacria (Sicily), whilst still farther west is the fabled land "Elysium," the region of eternal light, and the dwelling-place of the blessed; and beyond that, the stream of ocean which had to be crossed by disembodied spirits before descending into Hades, which was supposed to be situated beneath the Earth.

The second illustration which, as it will be seen, is more in conformity with the true theory of the Solar system, represents the views of Pythagoras and his school, and is generally called the Philolaic system, from its enunciator Philolaus, who lived and taught in the fourth century before Christ.

According to this school of astronomers the heavenly bodies were spherical.

In the centre of the Universe was the "Central fire," *not* identical with the Sun, but probably imparting to him his warmth-infusing rays. Next came the "Antichthon," the nature and functions of which are not clearly defined, but which is supposed by a modern writer† to have been a body that represented what in reality was the side of the Earth unknown to the ancients.

Then followed the Earth deriving its light and heat from the Sun, which was supposed to be external to it in the universe; after that came the Moon, next the five planets, and lastly the fixed stars. (See Plate XXIV.)

The Antichthon, Earth, and all the heavenly bodies revolved round the Central fire. The former was not visible from the Earth at any time, revolving with it, but sometimes interposing between it and the Moon, which it then eclipsed!‡

* Smith's "Ancient Geography." † Sir G. C. Lewis.

‡ The Antichthon evidently performed the functions of the Earth's shadow.

The zone of the fixed stars was the true Heaven or Æther in which the gods dwelt, and from whence they descended from time to time to favour the sons and daughters of Earth with their celestial society.

It would be impossible for us here to refer to all the teachings of the Pythagorean school. Their doctrines explained every celestial phenomenon, real or imaginary; the supposed distances of the heavenly bodies from the Earth; their motions; the eclipses; the milky-way, and *the music of the spheres*, which was supposed to exist although it was inaudible.

And wherefore, does the reader suppose, it was "inaudible?" According to some philosophers, it was in consequence of the "constant habit" of hearing it; whilst others attributed the silence of this harmony to its "extreme loudness!"

However, imperfect as these teachings were, they held their sway until, in the sixteenth century, Copernicus laid the foundation of that theory of the universe which places the Sun in the centre of our system, and converted the fixed stars into so many solar centres of other systems, at present immeasurably distant, but which the magic tube and the advancing intelligence of man are bringing nearer to us day by day. With these distant worlds mankind will no doubt one day be better acquainted than we are at present with the nature of those companion planets that accompany our bright and beautiful world in its annual revolution round the central orb of light.

"But why," some of our readers may be disposed to inquire, "in a periodical devoted to the popular exposition of scientific truth, are we treated to a dissertation upon the errors or crude conceptions of our forefathers, long since defunct and forgotten?"

"Why," we would ask, in reply, "is it pleasant to unbend, after the rigid and wearisome study of those subjects which tax our powers to the utmost, and to listen to the innocent prattle of our children as they discourse learnedly upon these all-important topics, and endeavour in their innocence to cut through those knotty problems which we are seeking laboriously to unloose?"

It is as agreeable to the modern student of science to look back upon the half-mythical theories; upon the imaginings of the earliest inhabitants of our globe, as it must have been to the parent who had taught his child that it was God who made the stars, to hear his little one exclaim, as the first twinkling light made its appearance in the heavens, "See! see! God has made a star!"

But there is also an important lesson to be derived from the consideration of this interesting subject, which recommends

itself especially to the attention of the student of nature, namely, that the operations of the great laws which rule the physical world may also be traced in the realm of mind.

There is a rule, well known to naturalists, in the development of the animal races, and one to which we have frequently had occasion to refer elsewhere, that those creatures which hold a higher place in the scale of life, have to pass during their life-time through the various stages which characterise the humbler forms in *their perfect* stage. Many examples might be adduced from the history of the animal tribes to illustrate this fact; but it is only necessary to refer to one, which we shall thus state familiarly. Man, in the course of his physical development from the germ to the mature being, passes through the various forms assumed by the lower vertebrates in their perfect state.

Now, the same law will be found to exist in the *mental* development of the individual, as well as in that of the whole human race. Each intellect, before it can become fully expanded, must pass through the stages of utter ignorance and semi-enlightenment, whilst the records of history show that the human race also has had an infant mind, and is passing through progressive stages of intelligence.

The ancient Greeks and Hebrews, who conceived that the stars were set in the vault of Heaven, may be ranged side by side with the child who says that God has made a star; believing that He has just set up a twinkling light in the heavens.

The more advanced Pythagorean, seeking to break through the cloud of ignorance which obscured the intellect of his age, and groping his way darkly towards the truth, resembles the youth who passes through the probation of his school-days; whilst the modern astronomer, who is still younger in knowledge compared with those who will succeed him, may be likened to the young man immersed in his collegiate studies: upon whom the principles of truth have dawned, and who will employ the remainder of his life in their practical application!

This is no fanciful picture; no vain and imaginary simile! It is but another illustration of the unity and simplicity of that law which regulates the affairs of the universe; alike bringing the humblest protophyte into existence, and developing the noblest of all living creatures—man! And it is the enunciation of the awful yet beneficent will of that one great Creator and Ruler, who has made, and who sustains and governs all things, visible and invisible—in the world of time as in that of eternity!

THE PHYSICS OF A SUNBEAM.

BY ROBERT HUNT, F.R.S.

TO reduce our inquiry into the most simple form, it appears necessary that the reader should be invited to accompany the writer into the dark room employed in his illustration of "Light and Colour;"—a room, indeed, so dark that even after the eye has accustomed itself to the absence of any illuminating power, it shall not be enabled to distinguish either the forms or colours of surrounding objects. Under such conditions the eye is a useless organ; the sense of sight is not excited, we have lost the power of distinguishing bodies, which we cannot touch. Some agent external to ourselves is required to complete the connection between us and distant objects—to excite, indeed, the sense of sight.

Let us perforate with a steel point the window-shutter; a sunbeam enters and falls on the floor, forming a disc of bright LIGHT. From this circle radiation takes place; and, although it may be faintly, still the reposed eye begins to *see*. The radiations have diffused themselves, they have fallen on the surfaces of the articles around us, and then again the weak rays have been radiated to the eye. The myriad delicate nervous fingers, which spread over the retina, are touched and they tremble at the touch. The varying sensations are conveyed to the brain and the phenomenon of vision is established.

If the hand be placed in the path of the sunbeam the sensation of warmth is communicated; we feel there is HEAT in the ray; or, if a thermometer is so placed that the beam falls upon its bulb, the mercury will expand and rise in the tube. Thus we have the evidence of two distinct classes of phenomena; a third awaits our investigation.

It is well known that photographic pictures are produced by a peculiar chemical change effected upon some salt of silver by the agency of the solar rays. If a piece of paper be covered with the chloride of silver,—which is purely white,—and if this be placed so that our luminous pencil falls upon it, the chemical surface will be rapidly darkened over the space covered by the sunbeam. The change which has taken place, and which is indicated by the alteration of colour, merits some attention.

Chloride of silver—the salt which we have supposed was the chemical compound employed—is one of the most stable character. So great is the affinity of chlorine for silver, that it will combine with, and separate that metal from, almost all its combinations. Yet the moment it is exposed to sunshine it is decomposed; chlorine is liberated and metallic silver is left behind. Such is the remarkable phenomenon; thus teaching us that we have to deal with agencies in the solar rays which are in their visible effects very dissimilar. It became necessary, when the investigations of science were directed to these peculiarities of solar chemistry, to distinguish by a name the agent which was at work. ACTINISM, a term signifying ray-power, was proposed, and it has been generally adopted to express the chemical principle of the sunbeam. The relations of LIGHT, *the luminous power of the sun; of* HEAT, *the calorific power, and of* ACTINISM, *the chemical power,* will now become the subject of consideration.

The plate accompanying this paper shows three spectral images; which, as they will serve to guide the reader in understanding the somewhat involved phenomena, should be carefully examined as we proceed.

The solar spectrum, which in its chromatic relations has been described in a former paper, must now be considered in connection with its illuminating power. The ray which has the highest illuminating power is the yellow. In either direction the light declines from this point. At the least refrangible end illumination ceases with the extreme red ray, and at the most refracted end there is no ordinary light beyond the violet; or, speaking with philosophical exactness, beyond the lavender ray, which terminates the violet, fading off gradually and beautifully into darkness: there is no illuminating power. Now the maximum of Light and of Heat are not coincident. Sir William Herschel and Sir Henry Englefield long since determined that the maximum of Heat was to to be found in the least refrangible rays. Sir John Herschel has a beautiful experiment by which this is proved, and some new truths added to our knowledge. A piece of silver paper is carefully stretched upon a frame, and being held above a very smoky candle or lamp it is blackened over on one side. After having been thus prepared this screen is placed so that the solar spectrum can be received upon the *unblackened* side. When a very perfect image has been obtained by an accurate adjustment of the prism, and the rays are seen in all their beauty of colour, well defined; the paper is thoroughly saturated with ether, which should be applied with a wide flat brush. The tissue-paper being wetted appears perfectly black, but, in a very short time, the heat-rays drying up this volatile fluid, a curious image is produced which is a picture indeed of the dis-

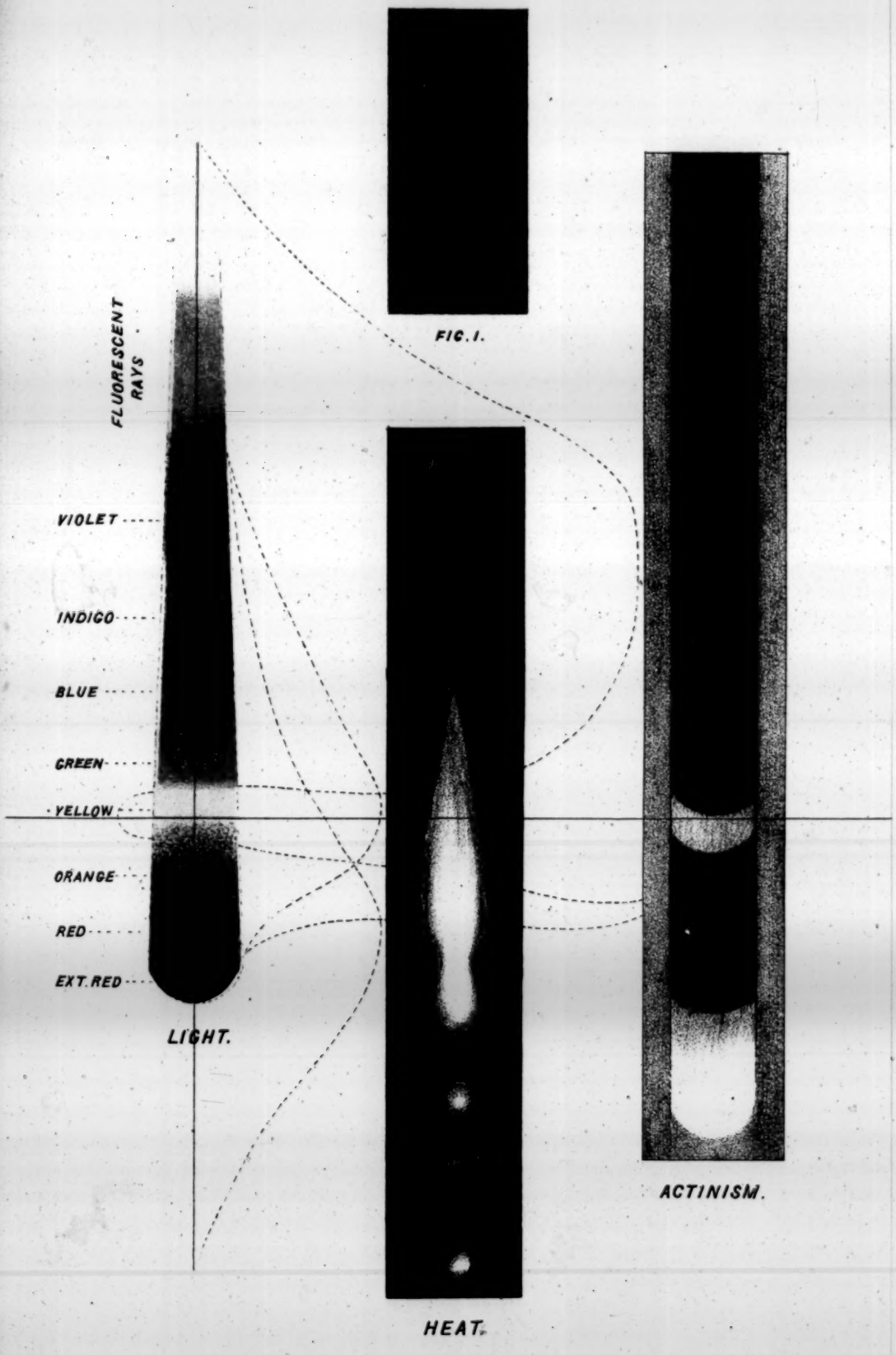
tribution of Heat amidst and beyond the coloured rays of the spectrum (see HEAT in the plate). The first spot dries over a space which is just below the extreme red ray, thus indicating this as the point of maximum calorific power. With gradually diminishing intensity, this drying goes on through the spectrum, presenting on the paper an image similar to that represented in the central figure of the drawing, all indication of Heat ceasing in the violet ray. While this result is being obtained over the space covered with coloured bands of light, three well-defined spots dry out below the red rays where there is no light. These are brought out with greater intensity if a second wash of ether be applied. The heat spectrum is thus shown to be of much greater length than the light spectrum.

Sir John Herschel discovered in these extra spectral heat-rays some peculiar properties; they appeared to possess all the ordinary properties of dark heat-rays, with some peculiar chemical power superadded; hence, to distinguish these from the ordinary heat-rays, it was proposed that they should be called the *parathermic rays*.

These heat-rays have been investigated by Mrs. Mary Somerville, and that lady has added some remarkable facts to the records of science. If the juices of flowers be expressed, and papers stained with them be placed under the action of those rays, many very curious results are obtained. Our space will admit of our describing one only, and that one is represented on our drawing marked fig. 1. In this particular experiment the coloured juice of the dark-purple dahlia was washed over pure white bibulous paper. This being exposed to the spectrum, was gradually changed, over the space occupied, by the parathermic rays, and a brown flame-shaped image was the result, with a spot of a dull red a little below it. By continuing the action, a peculiar internal action was seen to take place, and eventually four spots were formed over the brown space, two of these being red and two blue. It would thus appear that we had, by the action of these peculiar heat-rays, eliminated the two colours, which form, when combined, the purple of the dahlia.

It might be noted, that if chlorophyl, the green colouring matter of leaves, be taken and treated in this way, it is always turned brown by the parathermic rays. It is yet more curious that, at whatever period of the year we obtain this green colouring matter, the resulting brown is always that which marks the autumnal foliage of the plant from which the leaves have been gathered. Investigation continued over many years, shows that the quantity of these peculiar heat-rays varies with the seasons, and that they are most abundant in the sun's rays in the autumn. We may therefore infer that the ripening of fruits and grain, and the autumn tinting of the forest trees, are

THE SOLAR SPECTRA.



THE CURVED LINES SHEW THE POINTS OF MAXIMUM EFFECT.

due to those peculiar thermic rays which are entirely independent of Light though associated with that principle.

The scorching of the sun-beams, which is often observable in the summer and autumnal days, and which is not unusually associated with the appearance of blight on the leaves of plants, has been traced to an excess of these dark heat-rays.

If the spectral image by which the Light and Heat spectrum has been produced be maintained, and we substitute a paper or a glass tablet covered with any of the Photographic preparations, we obtain a spectrum such as is represented on our drawing and marked ACTINISM.

The Chemical tablet is blackened over some parts, and preserved unchanged over other parts. Upon that space which is under the influence of the most Light—as indicated by the line across the page—there is no indication of any change, however long the salt of silver may be exposed to solar action. The space covered by the Heat rays of maximum intensity is in like manner preserved unchanged. Over the region of the red rays some chemical change goes slowly on, and frequently a red colour is produced; in some cases, as when the bromide of silver is used, rising to a fine crimson. The yellow rays have no chemical power, but beyond them the decomposing agency is exerted with increasing force; it arrives at its maximum in the blue and indigo rays, and although it is weakened in force beyond these, the chemical power is exerted to a considerable distance beyond the visible spectrum, where there is no Light.

The results which have been described naturally open the question of the identity of Light, Heat, and Actinism, or the contrary. We have seen that the maximum points differ, and that where light and heat are the most energetic, there the chemical power is the least so.

According to the undulatory hypothesis these differences are explainable upon the supposition that one set of undulations will produce the sensation of Light, that another set establishes the sensation of Heat, and that a different rate of vibration again is the cause of Actinic phenomena.

There is some other evidence which it is necessary to bring before the reader. By means of absorbent media we may separate these agencies and examine them in action in an isolated state.

A slice of obsidian, or of black mica, will not allow any Light to pass through it, but it offers no obstruction to solar Heat.

A plate of glass stained of an apple green with oxide of copper is perfectly transparent to Light, but it is almost opaque to Heat. Glass which has been stained yellow with oxide or chloride of silver allows a full flood of Light to pass

through it, but it will not admit of the permeation of an Actinic ray.

If, on the contrary, we take a glass coloured to a deep intensity of blue with oxide of cobalt, we shall find this is almost dark,—but little Light can pass through it. Experiment will, however, prove that it offers no obstruction to the chemical rays.

Now, if we place the most sensitive of photographic preparations in a room, the Light to which is admitted through windows glazed with yellow glass, howsoever brilliantly the sun may shine, though the apartment be flooded with light, chloride, iodide, or bromide of silver will remain for any length of time perfectly unchanged.

Glaze the room with cobalt-blue glass, which is so dark as to obscure the Light, these salts will blacken with great rapidity; proving that, although the light has been obstructed, Actinism has suffered no interruption.

The strength of evidence appears to be in favour of considering Light, Heat, and Actinism as three distinct principles or powers, active in regulating the great phenomena of Nature. In the sunbeam these powers are balanced against each other, and thus are determined those differences of climate which are not influenced by the physical conformation of the earth's surface.

It has been proved by well-conducted observations, that with variations of latitude there are variations in the relations of these three principles.

In the temperate regions of the earth the Actinic power is active; as we advance to the Tropics, where Heat increases, and,

> "The sun shines for ever unchangeably bright;"

the chemical power is weak. The photographic picture which could be taken in London in a second or two, could not be obtained within the Tropics in less than a quarter of an hour. It often happens, indeed, that prolonged exposure under a blazing sun is insufficient to produce any chemical change. Everything appears to favour the view that the distribution of plants and animals on the surface of the earth is regulated by the balance of physical forces in the sunbeam.

In the Seasons we detect the same influences at work. Actinism or chemical power is greatest in the Spring; as the bright Light of Summer advances, the power of the Solar rays to produce any chemical change is diminished; and as we advance to Autumn, the peculiar Heat-rays come more evidently into action.

The ethereal agencies at work in the sunbeam play a most

important part in regulating all the conditions of vegetable life. Of many of these, experiments have determined the facts; a large field for inquiry is, however, still open to the industrious and patient searcher after hidden truths. The influences of Light on the animal economy are rather suspected than known. Experiments on animals present many difficulties which have not yet been overcome. Everything, however, proves the correctness of Lavoisier's poetic expression, "The fable of Prometheus is but the outshadowing of a philosophic truth—where there is Light there is organization and life; but where Light cannot penetrate, there Death for ever holds his silent court."

Light, Heat, and Actinism, existing in the sunbeam, are unceasingly at work. It has been shown by the investigations of the elder Niepce, and by Niepce de St. Victor, that it is impossible to expose any body, however solid and persistent it may appear, to the influence of sunshine without its undergoing a molecular or a chemical change. Glass, stone, wood, or metal, are, it can be proved, susceptible of Actinic change. The images of objects can be obtained upon them without any sensitive preparation; but they cannot be retained. In darkness all bodies appear to possess the power of restoring themselves to their normal state. If the solar rays shone *without interruption* on a granite monolith, or a bronze statue, it would perish, independently of other influences. Night is, therefore, as necessary to secure the permanence of the inorganic world as darkness and sleep are to maintain in healthful life the organized creations.

THE ENGLISH CALIFORNIA.

BY G. P. BEVAN, F.G.S., EDITOR OF "MURRAY'S HAND-BOOKS OF NORTH AND SOUTH WALES," ETC.

NEARLY all my readers have at one time or another seen a nugget—have handled it, wondered at its weight, and possibly its shabby appearance, and have involuntarily connected it with the arid hills of California and Australia, with hordes of undisciplined rapparees and savages (all the worse for coming from a civilized country), with tales of distress, starvation, robbery, and murder, with ne'er-do-weels, whom they formerly knew leaving the old country poor, and returning rich, after a few years' absence, with portmanteaus full of nuggets and carpet-bags full of gold-dust. But it has probably never struck them, that the same geological circumstances which have produced the material of those nuggets in a distant hemisphere have operated at home in our quiet British isles: in other words, that gold has been found and is to be found in no inconsiderable degree in some of our most picturesque and lovely districts, and that a simple question of quantity has prevented the English diggings from becoming the scenes of the same wild extravagance and of very wantonness of riches which have characterized those of Bendigo and Ballarat. Such is the case, however; and I will endeavour to show in this paper the geological conditions in which this, as any other gold produce, is found, and how far it is likely to become another ingredient of the permanent mineral wealth of this country.

Geologists have divided the whole of the rocks of the earth's crust into three portions, viz., Palæozoic, or Primary, implying the first and earliest division, as classified according to the fossil inhabitants in it; 2. Mesozoic, or Secondary, meaning the rocks which contain the middle zone of life in the earth's history; and 3. Cainozoic, or Tertiary, by which we understand the youngest and most modern of the divisions. For simplicity' sake we call them Primary, Secondary, and Tertiary, each of which is subdivided into numerous strata according to their fossil contents. It would be out of place to describe or even to catalogue the whole of these subdivisions,

and my only reason for mentioning them at all was to lay down a general rule, as applied to gold, viz., that it is never found in strata of Tertiary age, and but very rarely in those of the Secondary periods (except in the form of drifts, derived from older rocks). Indeed, as regards the Primary strata, it is almost always limited to rocks of the Silurian era, although it is occasionally observed in Carboniferous (coal-bearing) and Devonian (or old red sandstone) localities. We therefore perceive that the chance of finding the precious metal is at once considerably diminished by being limited to that portion of the earth's surface which is represented by Silurian, or perhaps, to speak more broadly, by primary rocks. The principal auriferous regions of the present day are the Oural Mountains of Russia, California, and Australia; and a few brief remarks on these goldfields may not be out of place, preparatory to detailing the position and features of our English gold.

We will take the Oural Mountains first, because they have been known and worked the longest, and are to a certain extent connected with Europe; besides which, they have had the advantage of being well examined and described by Sir Roderick Murchison. The enormous level area of Russia in Europe is occupied for the most part by primary rocks, and contains no gold; but, oddly enough, the same rocks, when thrown up into the broken and inclined positions which constitute the Oural chain, are auriferous in a very considerable degree. These upheaved ridges bear traces of great disturbance, and are pierced and permeated with porphyry, greenstone, syenite, and other plutonic rocks, the products of igneous action.

But here we have, as we shall see in the other cases, the great secret of the gold deposit, or, I should more correctly state it, as the infallible condition which accompanies the deposit, viz., the presence of porphyry or other igneous rocks in primary strata—a condition which will possibly give us a clue as to how gold is formed. The Oural hills are nearly all composed of strata of Silurian, Devonian, and Carboniferous age; and the gold was evidently not segregated or deposited at the time of the formation of these rocks, or else why is it not found in the contemporary districts of Russia in Europe? Moreover, Sir R. Murchison distinctly proved, from geological appearances on the flanks of these mountain regions, that the gold did not make its appearance until a very recent geological age; in other words, that the intrusions of the igneous rocks and the appearance of the gold were contemporaneous and recent. This is not merely a question of scientific interest, but bears heavily upon the more practical one of working the gold, as we shall presently see. The gold-bearing hills of Australia are very similar to those of Russia—the rocks which lie under the drifts

of gold being all sandstones, clays, slate, and grits belonging to the Palæozoic period. So much for the strata which produce the gold. Now we have to consider the position in which the metal is found and worked; and at the very outset we arrive at a practical conclusion—one which has been attained by many, many failures, and much bitter experience, viz., that it seldom or never pays to sink shafts for gold, since it has been proved in all the auriferous districts, that the richest find will be at the surface, and that the lower the adventurers sink the poorer in quality and less bountiful in supply becomes the precious metal.

The natural question then arises, as to the position of these drifts which have yielded so much gold and made so many fortunes. Let us, therefore, go back for a moment to the Oural Mountains. Sir Roderick tells us that the chief source of the metal is the accumulation of drift on the sides of the mountain, or the alluvium of the water-courses which descend to the valleys through the gullies; and the reason of it is this:—We must imagine a number of peaks and ridges permeated with intrusions of porphyritic rocks, &c., and impregnated with gold.

Denudation has largely taken place at one time or another, so that the outlines of these ridges have become altered, and a large quantity of material carried away and ground down to detritus of different sizes. It happens that, in the Oural chains particularly, we can fix the date of this grinding or denuding action, viz., at the period of the great glacial drift—a comparatively recent period, in which, nevertheless, the whole of the northern countries of Europe and Asia were permanently altered, from the ineffaceable quantities of material carried southward by the waters and icebergs of this Arctic period. We know, also, that what are now the northern portions of the continents were then inhabited by a singular kind of elephant and mammoth, adapted to the severity of the climate in which they lived; and accordingly associated with the heaps of gold-bearing detritus in the Ourals are found bones of these extinct animals, proving beyond all doubt the age of the drift. It is, therefore, not difficult to imagine why it is that these superficial gold-drifts are the richest, because not only do they bear in their bosom the materials from the surface of the veins which we have already seen is the most valuable, but the expense and labour of extracting and working the gold are as nothing compared with the expense of sinking shafts into the solid rock. Indeed, so well is this understood, that there is only one locality in the Siberian chain worked *sub-terrâ*, and that very sparingly. In Australia we find the same broad features, viz., that the gold-fields are in reality drifts of gold derived from the slaty primary rocks, and that the immense treasures extracted from them

have not been obtained as a rule by gold-mining, but from the surface. As might be expected, the finds have been most abundant in the creeks, gullies, and gutters of the now familiar mining language. But the drifts of Australia differ from those of Russia in being of a more remote age, although still considered to belong to the Tertiary period; and, indeed, Mr. Selwyn, the colonial geologist, has pointed out gold-bearing superficial drifts of three different stages or ages lying above one another, the oldest or lowest containing cones and traces of vegetation allied to that now prevalent in the country. But I have said enough to show my readers the usual disposition of the auriferous strata, and the conditions under which they are practically useful; and we will now come nearer home, where we find the gold in its original matrix in the solid rock; but, unfortunately, none of those fabulously rich reefs for the treasures of which so many people are annually risking their lives. And yet I do not know that I should say *unfortunately*, for if we have not the gold (which is limited and capricious), we have abundance of what is to us and the world in general, far more valuable—minerals, in the shape of iron, tin, lead, and copper, which not only create a steady market in themselves, but are the means of employing tens of thousands in the manufactures to which they give rise.

Every tourist in North Wales knows the lovely little town of Dolgelly, with the mighty mass of Cader Idris, at whose base flows the noble estuary of the Mawddach, dividing it from the great block of Merionethshire hills, stretching southwards from Harlech to Barmouth, the craggy Rhinogs, Craig-y-dwrg, and the broad slopes of the Llawlech, forming altogether a singular chain of mountains abounding in wild scenery that deserves to be more sought after than it is by the traveller. On the eastern side of this range is the wooded valley of the Cayne and Camlan, with their magnificent waterfalls, the most attractive lions of the Dolgelly neighbourhood.

Now this great Llawlech block is composed of a mass or boss of Cambrian rocks, which, in geological sequence, occur at the very bottom of the Silurian series, and are unfossiliferous, or nearly so. On each side of this Cambrian boss are layers of rock, known as Lingula flags (so called from containing the Lingula, a minute fossil shell), which, by a phenomenon known as an anticlinal line, are thrown off on each side, just as the coats of an onion might be. Above these Lingula flags are other Lower Silurian strata mixed up and interbedded with igneous rocks, such as porphyry, greenstone, &c. Here, then, we have the very sort of district which, as we have seen from Sir Roderick's observations, gold affects—a district of primary traversed by eruptive or igneous rocks; and here, accordingly, gold is found in about

twenty or more localities. At the Clogau mine, which is the most prolific and is still worked (situated 1,000 feet above the sea), they found a regular gold lode; not, indeed, of solid metal, but composed of quartz rocks, impregnated with ores of sulphur, iron, lead, and (very richly) with native gold, which occurs partly disseminated through the mass, but frequently in strings or "bunches." Mr. Readwin tells us that this was once worked as poor copper ore, and that the Flintshire copper smelters were averse to leaving it off, and even offered five shillings a ton more for its continuance! At the adjacent mine of Dolfrynog, Professor Ansted found gold also, occurring in grains and in thin flakes, together with crystals of galena (lead ore) and copper pyrites. The existence of this gold has been known for a long time, and various attempts have been made to extract it profitably; but somehow they have all failed, owing to the great cost of labour and machinery; for we must remember that we have not here the rich gold-bearing drift, although, by the way, a very slight quantity of gold was discovered in the marine drift on the slopes of the hill. There are two ways of extracting the ore: one by chemical and the other by mechanical means. The latter has been the most in vogue, and consists simply in extracting masses of quartz, and then crushing it by machinery. This was tried at Dolfrynog and also at Cwmhesian; but the costly character of the process soon made it anything but profitable; besides which, from the finely-divided state of the gold in the quartz and blende in this neighbourhood, it is almost impossible to prevent its escape during the operation of stamping. Mr. Dean, in a paper read before the British Association, in 1844, declared that the whole of the Snowdonian frontier was replete with auriferous veins; and it is certain that a company was started at Frodsham, in Cheshire, for procuring the quartz from North Wales, and crushing it here, with a view to extracting the gold.

The chemical mode is by amalgam, in which a certain quantity (by weight) of metalliferous mineral is triturated or ground up with so many pounds of mercury, on the principle that gold always exists in a metallic state, and that when it is present in minerals the mercury will dissolve it. This, however, was frequently a failure, owing to the mercury being capricious, and neglecting the gold to consort with other and less dignified minerals. The process is, nevertheless, used at Clogau, care being taken not to intrude any mineral which would neutralize the affinity of the mercury for the gold. The grand point, after all, is the result which has proved so successful in the patient hands of Mr. Readwin, who has for many years been experimenting on these Welsh ores, feeling certain that a practical gain was to be obtained at some time or other.

The experiments were conducted on quartz obtained from the Clogau mine, 1 cwt. of which was crushed and tested, producing eight ounces and five pennyweights of fine gold, the value of which is rather more than £3 per ounce.

From the same mine had also been produced 207 tons of quartz, 191 of which gave 241 ounces; 12, of better quality, gave 96 ounces; and 3 tons of best quality the enormous amount of 976 ounces: the whole quantity amounting to 1,314 ounces. This, together with an experiment on five tons a little before, yielded a total of 1,370 ounces, valued at £5,300; the cost of obtaining which he estimated at £300. There are, of course, exceptional cases, but sufficient to show what may be done; though, taking the bad with the good, Mr. Readwin considers half an ounce of gold to the ton of quartz to be the average yield. The total proceeds of gold for the last Christmas quarter amounted to £4,796, which he expects will be the average quarterly yield for the present year. With these results, we are surely justified in considering gold-mines as one of the staple products of our island: not to be looked upon as a treasure for fortune-seekers wherewith to indulge the "auri sacra fames," but, like all other mining ventures in this country, as another opportunity for the application of steady perseverance combined with the highest scientific knowledge and application.

CAVERNS AND THEIR CONTENTS.

BY D. T. ANSTED, F.R.S.

CHAPTER II.

CONTENTS OF THE CAVERNS, AND THEIR MEANING.

IN an article on "Caverns," in No. II. of the POPULAR SCIENCE REVIEW, something has been said concerning the history of these curious and interesting natural phenomena, and also of those remarkable columns, curtains, and fantastic structures of stone that are constantly growing and becoming modified in them by the action of water. It is also well known that occasionally caverns are the channels by which concealed rivers pass along out of sight from one part of the earth's surface to another; that sometimes the sea washes through them during a part of every tide; that some have, in ancient as well as modern times, served as the habitations of men or the dens of wild beasts; while others, only accessible from above, and only entered accidentally by any of the larger animals, are filled with stones and rubbish, with which valuable minerals and metallic ores are now and then associated.

The contents of caverns, then, is a part of the subject as varied as the history of the caverns, and capable of yielding quite as much matter of interest and information. We may consider in succession the mineral, the vegetable, and the animal contents, ranking among the latter those specimens of human art that have lately been found buried with the bones of animals.

Limestone caverns are not unfrequently mineral veins. The gaping crevices, partly filled with angular blocks fallen in from above, and partly with fine mud, have the interstices between the stones often occupied by glittering lead ore; or perhaps the floor consists of that stony ore of zinc called calamine, which seems to have been known only to the ancients as useful to convert copper into brass, and was not recognized by them as containing a specific and somewhat remarkable metal. Exposed to great heat, this stone-like mineral disappears as a white cloud (oxide of zinc), passing away into thin air. So

few of the common metals are volatile, that one can hardly be surprised at metallic zinc being a comparatively modern discovery.

Caverns in other rocks contain other minerals. In some of them native silver shoots forth from the walls in elegant strings, or the mixed ores of silver, lead, and antimony, with other less-used metals, are crystallized in various complicated shapes. Elsewhere, black, sooty walls mark the presence of manganese; and occasionally ores of copper, of extreme beauty, occupy niches in open spaces in slaty and granite rocks. But the great masses of valuable ores are not in caverns of the ordinary kind; and the mineral contents of caverns are more likely to consist of an irregular floor of stones bedded in mud than of gems and metals.

The vegetation found in caverns is less varied and less remarkable than the mineral wealth. A few ferns—some rare and curious, others common, but not less beautiful—are often pendent like a rich green fringe near the entrance and from the roofs and walls of those caves which open to the sea, while a floor of varied and tangled sea-weed marks the extreme point to which the ordinary tidal wave has access. One fern in particular, the sea spleen-wort (*Asplenium marinum*), though generally rare, is sometimes plentiful enough in such localities, and may be found in caves near Tenby, and elsewhere on the Welsh coast, and also abundantly in Devonshire, Cornwall, and the Channel Islands. Others have been found associated with it.

Owing to the darkness that prevails during the day as well as at night in the recesses of caverns, there is little growth there of any kind; nor is it at all usual to find much vegetable matter drifted far in. All that grows or is deposited near the entry of a cave is pretty sure to be found also on the rocks of the same nature close at hand, and offers little or nothing that is peculiar in its mode of growth.

Even in the animal kingdom the variety of species permanently inhabiting the recesses of caverns is very small. What there is, however, is curious enough; and these permanent residents deserve some notice before we pass to the principal subject of the present chapter, namely, an account of the creatures that have in old times made caverns their dens.

Of all modifications and adaptations of structure, that of the very remarkable blind reptile found in several large caverns traversed by water, in different parts of the world, is certainly the most singular. This animal, the *Proteus anguinus* of naturalists, is a kind of salamander, or may be understood better as something between an eel and a tadpole. It is a foot long, of the size of a human finger, with four little legs, too imperfectly developed to be of any use as limbs. It has no

fins; but two curious coral-red crests, or naked gills, close to the fore-limbs, are combined with true lungs, giving the animal a double system for the aëration of the blood. Its jaws are well furnished with teeth, and its nostrils are large; but its ears are covered by flesh and skin, and the eyes are not only excessively small and rudimentary, but are also covered by skin, although represented externally by small points. This very curious little animal is aquatic in its habits, but can live perfectly well out of the water; and the species mentioned has only been found in the deepest recesses of the gigantic caverns of Adelsberg, in Carniola, where there is a subterranean river and lake. A somewhat similar animal is found in the mammoth cavern of Kentucky. As these creatures are carnivorous, there must evidently be a supply of other animals equally well adapted to live in perpetual darkness; but none have yet been described. It is curious to contemplate a whole creation probably deficient of an organ which seems essential to the happiness and health, if not the existence, of the rest of the organic world.

The animal life found in those caverns which are gloomy only, and not absolutely dark, and which are subject to the alternate flux and reflux of a large tide in a narrow sea, is beyond all comparison interesting, beautiful, and varied. The appearance of living and flourishing groups of sponge and coral, the numerous star-fishes and other radiated animals,—many of them very rare, the inconceivable multitude and variety of form and colour of the well-known sea-anemones, and the curious variety of marine worms,—all these, if seen for the first time under favourable circumstances of scenery and weather, produce combinations that no one can fail being interested in.

"In such spots," says M. Quatrefages, in his 'Rambles of a Naturalist,' "where every stone is a world within itself, I was able to contemplate, in its incredible variety, the domain of the lower marine animals: here I could admire, in all their glory, those unknown wonders of the deep of which even our best museums afford not the least idea; for these animal forms droop and, as it were, fade from view when they are removed from their native element. The *Turbo* (or top shell), the *Buccinum* (or Whelk) with its brown and white markings, and the *Balanus* (Acorn-shell) with its pyramidal plates, covered every stone and rock. In sheltered nooks I found the pretty little rose-coloured Cowrie and large Chitons, animals in which the back is covered by a solid cuirass composed of movable pieces like the greaves of old. Then there was the *Thetys*, a kind of sea-slug of a fine orange-colour, which bears its tuft of external lungs on the hindermost part of the back; and the *Haliotis** (ear-shell), with its nacreous shell surrounded by a triple row of fringes.

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* This animal is common in the Channel Islands and on the French coast, but does not extend to the coast of Britain.

The vaulted roof of these caverns, formed by the crumbling away of the rocks, was clothed with a mammilated stratum of simple Ascidians, which live and die without moving from the same spot; while from this bright-red ceiling there hung, like so many girandoles, transparent crystal-like *Clavellinæ* and the bright *Botrylli*, whose conglomerated masses exibit the colours and translucency of the agate. The smoother stones were all covered with Compound Ascidians, which were spread over the surface in shining green, brown, red, and violet patches, interspersed with markings of geometrical regularity, which severally indicated the different family groups of these singular beings. Among the animals appeared thousands of Zoophytes, while Star-fishes of the finest carmine, and greyish-brown Ophiuras, with their five long and slender arms, lay hidden beneath the stones. Above them the *Flustra* spread out its little stony weft, *Sertularias* and *Campanularias* raised aloft their arborescent polyparies, resembling miniature shrubs, while the *Eschara* threw its microscopic cellules over the stems and fronds of the marine plants. Sponges of every form and colour were intertwined among the branches of the fucus and attached to the sides of the rocks, either in thick masses or in interlacing meshes of delicate net-work. Here and there the *Thetya* might be seen, its rounded lobes bristling with little specula, side by side with the finger-like masses of *Alcyonium* and *Lobularia*, while sometimes a *Holothuria* (or sea-cucumber), with its long, polygonal, whitish body, would slowly move across this living tapestry, by means of its sucker-like feet, spreading abroad its coronet of arborescent tentacles."*

Such are the living contents of marine caverns, not only in the little islands of the Chaussey Archipelago, as alluded to more especially by M. de Quatrefages, but in the wonderful Gouliot caverns of Sark, in the smaller but interesting caves of St. Catharine's, near Tenby, and in many others less celebrated on other parts of the coast of England and Europe.

But caverns are sometimes tenanted by other and very different races. In countries little cultivated, and where wild animals are common in the adjacent forests, the bear, the hyæna, and some other beasts of prey, occupy caverns as dens, or use them either as larders or as burial-places. Sometimes they bring in and deposit there the carcases of their victims, sometimes they would seem to retire there to die. The skeletons and bones accumulated from either of these habits are not unfrequently heaped in quantities almost incredible, and they are sometimes mixed with and sometimes coated with recently formed stalagmite. Elsewhere, bones, shells, and various remains of animals have been washed into caverns on the occasion of some unusual flood, or have fallen in from above with stones, boulders, or angular fragments of rock. The caverns are thus sometimes floored with bones near the entry; sometimes the deeper recesses are choked with them to a great depth; and

* "Rambles of a Naturalist," *vide supra*, translated by E. C. Otté, vol. i. p. 38.

sometimes they have been quite filled, leaving no room for modern additions.

The entrances to land-caves containing these remains of animals are usually on some hill-side; and even many marine caves, such as those very remarkable ones at Gower, in South Wales, have, as the only access, some hole seen halfway up a steep and precipitous cliff.

The singular caverns of Yorkshire and Somersetshire, and some of those in Derbyshire; the caverns on the banks of the Meuse, near Namur; those of Franconia, in Germany; those of Sicily, and many others very remarkable for their osseous contents, are unmistakably above the level of any running water in the vicinity. Most of them are more, many of them much more, than sixty feet above the adjacent valley, through which streams run. A question hence arises as to the mode in which water can have had access; and often there are no convenient paths by which a large animal could now drag its prey. There is thus suggested a difficulty which a little further investigation tends to increase rather than explain. The animals whose remains are so abundant are not merely now absent, but no account of their existence in a living state is handed down to us. Nay, so far from the species being either familiar or historical, we are inclined to suppose that they never could have lived in the neighbourhood so long as the land and water and the climate existed as they do now. Perhaps this idea is not quite so well based as people have generally believed. In England and Western Europe the animals whose remains are most common in caverns are a very gigantic species of bear, now nowhere met with, but more resembling the grisly bear of California than the black bear of Europe, and a gigantic species of hyæna, compared with which the largest existing species is not worthy to be named. Moreover, this hyæna is related much more closely to the southern type peculiar now to the Cape of Good Hope than to the hyænas of Abyssinia and Asia Minor. When, therefore, we find indications of a long succession of such tribes, and that they carried into their dens the bones, not only of deer and oxen and other animals now belonging to the surrounding country, but of some altogether gone and lost to us, there is additional reason for assuming that the caverns teach a lesson in the history of the world, and require special consideration.

Among the creatures that inhabited Europe at the time when the caverns, or some of them, were the dens of wild beasts, we must rank the elephant, the rhinoceros, a remarkable deer of very large size and with horns of enormous spread, and a distinct variety, if not species, of bovine animal, of which the Aurochs of the Lithuanian forest is the nearest type. That

such animals ranged over the Continent and occupied England at a period not very remote in comparison with the general history of the earth, there can be no doubt. That they were abundant and indigenous would seem equally certain. Whether dry land connected England with Europe, or whether there were means of which we know not, enabling the gigantic quadrupeds to journey from the one to the other land, it would be idle here to speculate; but at any rate they lived and died on the banks of rivers whose beds are now in many cases several fathoms below the position they formerly occupied, and the materials of the floors of the caverns were either drifted in by accident, or carried thither intentionally by contemporary animals.

While the caverns of Europe abound in the bones of such races as we have just referred to, it is extremely curious and interesting to find that an almost similar difference between the animals of the caverns and those of the green fields and forests existed at the antipodes. It is now several years since a number of remarkable caverns were opened in South Australia by Sir W. Mitchell, and yielded a result not less remarkable than those of Germany and England. In them, also, we find the bones of carnivorous and herbivorous animals mixed together. The carnivora were such as would carry dead prey into a den; the herbivora were probably the common quadrupeds of the plains. As, however, that part of the world (Australia) is now peopled by kangaroos and wombats, and some herbivorous quadrupeds of moderate size, all having the structure called *marsupial*,* so the caverns contain numerous carnivorous and herbivorous species, also marsupial, but of dimensions and proportions singularly gigantic, and all now extinct. Whether from some sudden or gradual destruction and replacement of species, or, which is much more likely, from some slow modification resulting from altered conditions of existence, there would appear to have been, both in Australia and in England, a state of the land vastly more favourable for the existence of the largest quadrupeds at the time just before the historic period, than has happened since, or that we have any evidence of at an earlier date. For some reason unknown, this time coincided with such a position of the entrances of caverns as enabled the wild and powerful carnivora to make use of them, and drag thither their prisoners. This period was not a brief one, and may have commenced very long ago, when the dif-

* By marsupial is meant that the young are brought into the world in a very imperfectly developed state, and are long afterwards carried about by the mother in a *marsupium*, or natural pouch. It is conjectured that the rarity of water in Australia, and the long distances animals are obliged to travel without this necessary of life, may be reasons for this provision.

ference of inhabitants was far greater than lately; but the conditions of existence changed but slowly during its continuance.

Judging from the present position of the entrances of many of the principal bone-caverns, there must have been a considerable elevation of extensive tracts in Europe since or during the period we refer to. Such an elevation must have tended to increase the quantity of land in the northern hemisphere, and in this way to modify and render less equable the climate of the temperate latitudes. As by degrees the change established itself, and large tracts of low flat land—the great plains of Germany—rose above the waves, and became clothed with forest,—the higher lands meanwhile becoming hills and mountains—one can readily imagine that the conditions favourable for these monsters may have altered; that different races, smaller but more active, took their place; and that, by the time the change had been completed, the elevation should have carried out of reach the former habitations. Certainly there are few cases known in which caverns near the present level, either of the sea or of the adjacent valleys, have been found to bear marks of the habitation of ancient tribes of carnivora.

In the south of Europe, and in somewhat earlier deposits also in the north, at least as far as Britain, there are very numerous remains of hippopotami, and in India the number of extinct species of this singular animal is wonderfully large. At the time when so aquatic a tribe, and one believed to require so high a temperature, could live in England and Northern Europe, there must at any rate have been a very different condition of things from that since prevailing.

South America also has its bone-caverns, and these are neither few in number, nor doubtful in their indications. What the various marsupials are to Australia, the equally special and well-marked edentates are to Brazil, and other parts of the vast tract of country between the Andes and the east coast of South America The sloth, the armadillo, and the ant-eater, are the characteristic animals. In the caverns and in the mud-banks, where there is no limestone at hand to be penetrated and eaten away into holes, we find the ancient representative of these modern tribes. The difference here, however, is even more marvellous in extent than either in Europe or Australia, though similar in kind. In the place of the sloth, we have giants as remarkable for their massive proportions as for their size, though in that they exceed the elephant. Instead of the armadillo, there is a creature whose cuirass is not only larger, but harder and tougher than that of any living animal supplied with such defence. So also the ruminating animals are represented in similar proportion; and all point to con-

ditions eminently favourable for animal development, at least as regards size and proportions.

In South America, however, as in England, the caverns were occupied, and these monsters lived when the land was smaller, not larger than at present. Much of the width of those steppes that now conduct from the Atlantic to the foot of the Andes must then have been submerged, and have formed the ocean floor. The Andes were less lofty—the wall between the Atlantic and Pacific a less complete barrier than it has since become. The date of occupation of the caverns was one marked by great difference of climate, arising from great difference in the physical features of the land.

In alluding briefly to three principal districts of the earth as affording special evidence concerning the cavern period, it must not be supposed that bone-caverns are confined to them, or that there is reason to suppose that the occupation was contemporaneous. It does, however, seem certain that from a time when the present features of the land began to be developed down to a very late period, when men began to be civilized, there existed many races of large animals that have been destroyed, and also that, during the long time that elapsed, very important and extensive changes took place in the relative level of land and water, and in the physical features of the land.

The reader may be inclined to ask if any physical evidence exists of a sudden and violent disruption at any time of existing conditions, and a possible destruction of old and introduction of new races of animals. To this the geologist must reply in the negative. There is no such evidence in any part of the world on a scale large enough to deserve attention. Local disturbances have probably been repeated frequently, but of any change affecting the whole surface there are no indications whatever.

Among the objects of interest found in caverns, those that have reference to the human race are naturally the most interesting. When, therefore, fragments even of the rudest kind that indicate human intelligence in their manufacture are met with in association with ancient bones, it is not surprising that much attention should be directed to the discovery. Few, however, hitherto, are the cases of this kind, except when it is easy to refer the fragments to a definite period. Occasionally there have been found spear-heads and other articles of metal, small fragments of coarse pottery, and even beads, proving that the caverns had been for a time human habitations or sepulchres. All these, however, have reference to people of whom we know that they had already advanced far in the pro-

gress towards civilization. They were people of known races, and in many cases their descent and origin may be traced.

Once or twice, however, it has happened that the mud of the caverns has yielded yet ruder, much less useful, but even more interesting, human remains. Mixed up with the bones of the great cave-bear, the huge cavern-hyæna, the elephant, and the rhinoceros, and weather-worn like other stones of the same material, there have been found numerous flint and other stone weapons buried under stalagmite, affording unmistakable proof that a far more ancient race of men—savages of whose origin and history we know absolutely nothing—must have preceded the men of the historic period by a number of years quite unmeasurable. That this time was very great is probable; but nothing more can be said as to its amount. That it was sufficient to allow of the destruction of numerous races of gigantic quadrupeds and the introduction of many new groups, may be said to be certain.

The objects thus found are simple; and they have been met with much more plentifully in gravel-beds than in caverns. In both positions, however, they tell the same tale. They are flints, or other hard stones, chipped by human hands into a form believed to be meant for arrow or spear heads. Occasionally, flakes or fragments of flint broken off by a single blow, or a little more elaborately prepared, are mixed with them. They are weathered and whitened like other fragments of similar mineral found near them in the same bed, bearing no marks of having been artificially broken.

One result would seem certain from these discoveries in caverns; namely, that some members of the human race lived long enough ago to have seen the singular group of gigantic quadrupeds briefly described in a former paragraph, and to have fought with them: they may even have inhabited similar caves.

On the other hand, however, it is equally clear that these large animals may have lingered in many parts of the world to a comparatively recent date. There is no positive evidence one way or the other. That it would take long to expunge from the world some of the largest tribes, and replace them by others, is probable, but not certain; and when it is considered that even up to the present time we are by no means sure whether the gigantic bird of New Zealand (the *Dinornis* or *Moa*) is really an existing or extinct species, the danger of dogmatizing on the absolute date of the final destruction in Europe of the bear, hyæna, elephant, rhinoceros, or huge antlered elk, is apparent.

Still, the association of man with such animals as those we have alluded to in the places where their bones are found is a phenomenon that does not seem to be confined even to the

latest part of their history; and the balance of evidence renders it probable that the human race in a very early stage of development has been much longer upon the earth than is generally supposed. How long that stage of non-development, or imperfect development, may have existed, there are, as yet, no means of determining.

What a singular history, then, do these caverns afford, and how important is their geological bearing! One can imagine no good reason why those which were once inhabited should be limited in date to a period so recent as to include among their inhabitants the contemporaries of man; and yet, although they exist, and are even abundant, in the older limestones,* no trace has ever yet been found in them of the inhabitants of the land during any more ancient part of the earth's history. In the rocks themselves there are proofs enough of near land; quadrupeds, birds, and land shells, besides numerous fragments of land vegetation, are found there; and the land must have been not only near, but tolerably extensive. Why, then, is it that no fragments of the gigantic saurian or the marsupial rats of the middle period are met with among the mud at the bottom of the caverns?

To questions like these but little answer can be given. It may be that such vestiges really exist, but remain as yet undiscovered. It may be that the entrances to the caverns were not conveniently placed with reference to the general level of the land and water at the time. When the entrance to a cavern is below the water, or high up on the steep face of a cliff, whether above the level of the sea or a river, it is clear that there will be few remains of the life of the period preserved within its shelter.

And coming nearer to our own time, the question will also be asked,—What manner of men were these ancestors of ours—these indigens who inhabited the holes in the rocks, or who made use of them for storing their implements or burying their dead? Here, again, the answer is little satisfactory, but the facts are eminently suggestive.

Concerning the various weapons, or tools, or whatever else the human remains buried with hyænas' and bears' bones may have been, one fact is very significant, namely, that in all parts of the world—in England and France, Germany and Italy, Russia and Scandinavia, everywhere, in a word, throughout Europe—these remains, wherever found, are in all essentials the same, and are not unfrequently of foreign material. This, of itself, is interesting; but when we find that from the interior

* The limestones of the carboniferous period contain by far the most remarkable of the caverns in England and Wales and North America. The oolitic limestones are chiefly caverniferous in Germany, and tertiary limestones in Sicily.

of India and China, the banks of the Mississippi, and the vast plains of South America, specimens of sculptured stone are obtained always precisely similar—that the jade of the East is mixed up in the caverns and gravel with flints from Western Europe, and with greenstones from America, and that even the northern parts of Australia and Madagascar appear to contain examples of manufacture differing from these nothing in style and little in material—we are reminded pointedly of the original unity of the human race, and we see that an undetermined question of time forms the only serious difficulty interfering with the reception of one of the most startling innovations resulting from modern geological investigation.

Caverns, then, teach many truths in geology. First of all, they point, in their very form and in the mere fact of their existence, to the grand operations of nature carried on out of our sight in the deepest recesses of the earth,—the conversion of mere heaps of mud and sand into definite stratified rocks, hard, durable, and characteristic. Next, they teach us how, when the rocks have been elevated, water has acted upon them not only externally, but widening the narrow channels, removing and clearing out large spaces, and again filling them up with different material. Thirdly, they show the nature of the inhabitants of a former state of the earth's surface, when climate and other physical causes determined the presence of races that have long since departed. Fourthly, they lay bare, sometimes in the most singular manner, the secrets of marine life, and invite to a study of nature under circumstances of peculiar variety and interest. Fifthly, and lastly, they tell us a part of the great story of human existence, and of the association of man with many extinct races of gigantic quadrupeds, known only by their skeletons, but certainly characteristic of a geological period.

THE MICROSCOPE;

WITH DIRECTIONS FOR ITS USE.*

BY CUTHBERT COLLINGWOOD, M.B., F.L.S., ETC.

IT may be said that there is scarcely any instrument of a philosophical character which, placed in the hands of one unaccustomed to its use, at once suggests the method of its satisfactory application. Explanations are necessary, methods of manipulation have to be pointed out by some one who has already mastered its details, and learned the uses of the various parts, and the practical application of the whole. And particularly is this the case with an instrument so complicated as the Microscope, the beautiful adaptations of which may be missed in the absence of a guiding hand, the results impaired for want of fully comprehending the means of arriving at them, or the delicate parts may be injured by the too rough usage of an inexperienced tyro. It has sometimes been our lot to meet with persons who, surprised at the marvels, or delighted with the beauties of the natural objects that have been casually shown them through the Microscope, have forthwith determined to be themselves the happy possessors of so enchanting an instrument. The Microscope, obtained perhaps at great cost, arrives, is unpacked, and the source of a thousand innocent and intellectual gratifications stands before its owner, a useless machine, for he has not the skill to use it, and perhaps is almost afraid to touch it, lest he should do it some injury. The beautiful objects seen through the previous instrument cannot be observed by this, or are only so partially and obscurely viewed as to give rise to blank disappointment. He may, perchance, know no one to whom to apply for an explanation of the various parts, and disappointment is followed by vexation, and the instrument laid aside in disgust, just for the want of a hint or two of a practical nature, the result of which could not fail to stimulate further inquiries. It is to such of our readers as may be thus situated that the following pages are addressed,—to *beginners* with the Microscope, who are in search of some brief

* We publish this paper at the request of numerous correspondents.

but plain directions *how to use it;* and it is hoped not only that a short paper on this subject may not be unacceptable to those who are thirsting to explore the boundless field of minute organic life, but that others may be induced by its perusal to possess themselves of an instrument with which they may thus at once, and with little difficulty, render themselves familiar; so that the band of scientific investigators may be reinforced, and the mass of valuable results be increased.

The great optical principle which lies at the foundation of the Microscope is termed *Refraction.* By this term is expressed that change in its course which a ray of light makes in passing from one medium to another in an oblique direction. If a piece of stick be dipped perpendicularly in a basin of water no distortion appears, but the stick is seen to be straight as in the air. Depress, now, one end of the stick, and the part which is immersed in the water appears bent or distorted. The ray of light (or the stick) passing obliquely from the rarer medium (air) into the denser medium (water), is bent in such a manner as to approach *towards* a plumb-line let fall through the point where the air, water, and stick meet. It follows, therefore, that the ray which passes in the other direction, namely, from the water (the denser medium) into the air (the rarer), is bent in the opposite direction, namely, away from the perpendicular plumb-line; while the light which passes in the direction of the plumb-line itself, in or out, undergoes no contortion, bending, or refraction. The same thing that happens in the passage of a ray of light from air through *water,* takes place in its passage from air through *glass,* only glass being more dense than water, the refraction produced is greater. Taking advantage of this simple property of light, pieces of glass have been constructed of such forms that the rays of light received by the whole surface of one side are so refracted that they all meet at one point (termed the focus) on the other side; the distance between the centre of such a piece of glass and the focus being termed the *focal distance.* Such a piece of glass, termed a lens, *magnifies* by enabling the eye to see the object at a shorter distance than would otherwise be possible, thus causing the rays of light from the object to enter the eye at a wider angle, and thereby enlarging the image impressed upon the retina. Those lenses which are convex on both sides, as an ordinary burning-glass, are most common; but in compound instruments, this form of lens is sometimes combined with others, as the plano-convex, plano-concave, concavo-convex, and double-concave.

A common pocket lens consists of such a double-convex lens, which has the same enlarging effect as a glass-bubble filled with water, one of the most ancient forms of microscope. Two or three such lenses combined increase the effect. But the great

difficulty to be overcome in the construction of such lenses is of a twofold character, viz., first, *spherical aberration*, or the distortion caused by the failure of all the rays to meet precisely in the focus, owing to the imperfection of the curvature of the lens; and *chromatic aberration*, which arises from the different degrees of refrangibility of the different coloured rays which unite to form ordinary white light. The first difficulty is surmounted only by more delicate and improved workmanship; the second, by an ingenious combination of different kinds of glass (as crown glass and flint glass), which possess different powers of dispersing the coloured rays,—the one correcting the other. For simple microscopes this contrivance at once obviated the inconvenience arising from the coloured fringes surrounding the image, to which the name of chromatic aberration was applied; but the minuteness of the lenses used in compound microscopes led even distinguished opticians to believe that these great difficulties could never be sufficiently overcome to render such compound instruments of any real service. The clearness of definition, and the absence of colour observable in even the higher powers now in use, afford sufficient proof that these fears have vanished before the advance of skill and science.

A *simple* microscope, then, consists of either a single lens, or of two lenses combined so as to act as one, and fixed upon a stand, so that it can readily be adjusted to an object, and at the same time kept more steady than it could be by the hand. A framework to support the object, and a mirror to collect the light upon it, complete the arrangement. Such a microscope as this, simple as it really is, is very useful for many purposes, particularly for the dissection of vegetable structures, or such objects as it is desired to tear up or anatomize under assisted vision; and it is to such an instrument as this that the earlier microscopic observers were indebted for those discoveries which laid the foundation of the present vast accumulation of microscopical knowledge.

The *compound* microscope, being the form now in general use, and for the perfection of which the ingenuity of the optician and the mechanic has been taxed to the uttermost, is that to which we would direct especial attention. Like the simple microscope, this instrument may consist of only two lenses; but these, instead of being simply combined to produce the effect of one, have totally distinct functions. One of these, nearest the object (the objective, or object glass), collects the rays from the object and brings them to a focus, producing an image, which is scrutinized by the other lens as though it were the object itself. This second lens is called the eye-glass, and the separation which is obviously necessary between these two lenses, and which is equivalent to the focal

distances of the two, produces a necessity for a tube or body in the compound microscope, which the single instrument does not require.

But in the completer form of compound microscope another lens is employed, which is inserted between the object-glass and the image produced by it. This glass serves the important purpose of so changing the course of the rays as to diminish the size of the image, thus allowing the whole of it to come within the range of the eye-glass, and enlarging the field of vision. Hence it is called the *field-glass.* It has, however, an important relation to the eye-glass, which, together with it, is called the *eye-piece.* (Fig. 1.) The most useful eye-piece consists of a plano-convex field-glass and a similar eye-glass, the plane surfaces of each being towards the eye, and a *diaphragm* or *stop* being interposed between them, so that only the more central rays are allowed to pass, the distortion arising from spherical and chromatic aberration being thus avoided.

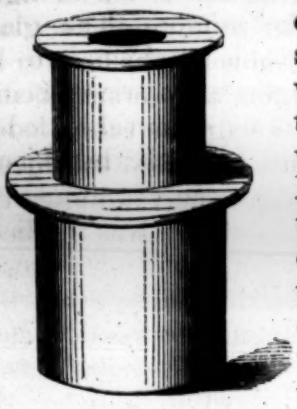


Fig. 1.

The general *optical* principles concerned in the construction of the compound microscope being understood, the various modifications and matters of detail must be mastered at leisure, being, in fact, not the sudden and easy application of principles long known, but the laborious and careful result of ceaseless experiment and research. But there are other principles to be applied, of a secondary nature it is true, but still scarcely less necessary for the efficient working of the instrument than those to which brief reference has been made. These are the *mechanical* arrangements, the stability of the whole apparatus, its capability of accurate adjustment, and the convenient mutual relation of all its parts. These, perhaps, will be best illustrated by a description of the various parts of an ordinary compound microscope, such as that of which a drawing is given at fig. 2.

In this microscope it is first to be observed that the tripod stand affords a firm basis of support, so that there is no fear of the instrument being readily overturned, or even moved by any ordinary manipulation. The two pillars upon which the microscope itself works are solid, and with the feet are altogether of a considerable weight, thus preventing any movement or vibration in the instrument, which is securely screwed between them. This is extremely important, since any vibration is communicated to the object in an increased proportion, according to the magnifying power used. The microscope itself consists of two

parallel columns united by a solid cross-piece; the lower column (suspended between the pillars of the stand) bearing the illuminating mirror, stage, rack-work, &c., the upper column being the body or tube of the optical instrument, with its objective and eye-piece. Fixed to the middle of the lower column is the *stage*, a flat table, having an aperture situated immediately in a line with the tube of the microscope, for the admission of light from below, which is thrown up by the mirror. The glass slide containing a mounted transparent object which is to be viewed by transmitted light, is placed upon this stage, being secured from slipping out of its position by a movable ledge which is readily adjusted so as to secure beneath the object-

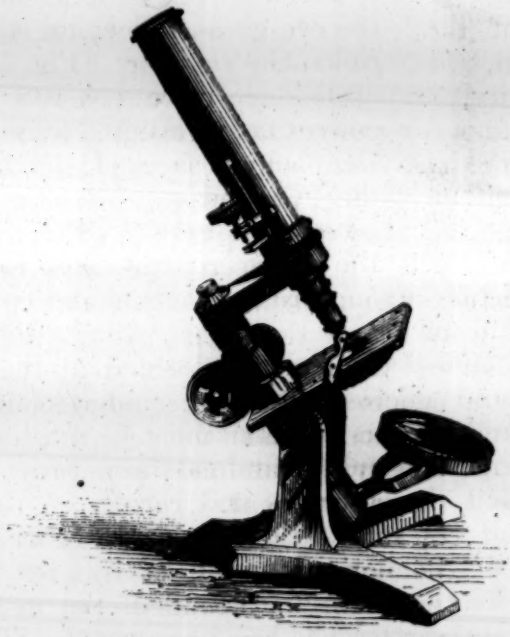


Fig. 2.

glass the particular portion of the object which it is desired to examine. This stage is sometimes furnished with a pair of milled-heads which move it forwards or sideways at pleasure, so that any moving object may be kept in the field without the necessity of touching the slide or cell containing the object. Immediately beneath the stage is a circular plate called the *diaphragm*, with perforations of various dimensions, from the size of a pin's head to that of the aperture in the stage itself. These openings regulate the amount of light admitted, very transparent objects being scarcely discernible in the full glare of light admitted through the large apertures, which, however, are necessary for the examination of objects of a more opaque character, which require all the light obtainable. At the foot of the column is the concave mirror, which, being

moveable in all directions, throws up the light which it reflects from a window, or a lamp, upon the transparent object which it thus illuminates from beneath. The upper part of this column is provided with a pair of large milled-heads, by turning which, the tube of the microscope, together with the solid cross-piece to which it is fixed, can be raised or lowered by means of a rack-work attached to a short stem which slides up and down in the upper part of the column. By this means the focus can be adjusted without the necessity of moving the stage, which in all the best microscopes is a fixture to the lower column. This is termed the *coarse adjustment*, and, for low magnifying powers, is all that is needed for regulating the focus.

The tube of the microscope itself, which is thus raised and depressed, has the *objective*, or *object glass*, at its lower extremity, and this can be unscrewed (fig. 3) and replaced by another power at pleasure; and at its upper extremity is the *eye-piece*, which is also readily pulled out (as at fig. 1), either for the purpose of cleansing it, or for the insertion of another kind of eye-piece. About midway up the tube is a small milled-head (seen edgewise) connected with what is termed the *fine adjustment*. A very slight movement of this milled-head alters the focus, when high powers are used, so that, having brought the object roughly into focus by means of the coarse adjustment, the utmost precision and the clearest definition may readily be obtained by a turn or two of the fine adjustment. Finally, in the description of this microscope only one thing more need be noticed, and that is, that the whole instrument is suspended (neither too stiffly nor too loosely) upon the two screws at the upper part of the pillars of the stand, so that it may be placed in a vertical, an inclined, or even a horizontal position, at pleasure, without moving the stand. This is an important advantage; for whilst various degrees of obliquity are often requisite to meet the convenience of the observer as he sits in his chair, or to take advantage of the position of the light, it is sometimes desirable to place the instrument in a vertical position, as when examining objects in water, while the horizontal is a no less useful position for certain purposes.

Fig. 3.

Let us now suppose the microscope placed upon a firm table, and the observer, with all his apparatus ready at hand, seated before a window. This leads us to make some remarks upon the *illumination* of the object. Daylight, when it can be used, is preferable to artificial light,—not direct sunlight, which is

too powerful, but strong, diffused light, which can be used with much more comfort than artificial light, and at the same time affords a more satisfactory view of the object under examination. But as it generally happens that the microscope is taken out when the busy labours of the day are over, some kind of artificial light is requisite; the great desideratum being a light which will not flicker, but will burn steadily, and give as pure a flame as possible. Gas may easily be brought down from the burner by an elastic tube communicating with a portable lamp upon the table; and, for those who have gas, this is, perhaps, the simplest expedient. The expensive solar and argand burners are, however, now in a great measure superseded by very inexpensive and manageable *paraffin lamps*. A lamp of this kind can be purchased at an oilman's or lamp-seller's for prices varying from one shilling upwards; a really elegant lamp, particularly when lighted, being obtainable for the small sum of two shillings, or half a crown. The oil burned in these lamps requires, however, a word of comment and caution. The ordinary cheap *paraffin* oil is liable to give off an explosive vapour, which might lead to serious accidents. A simple test of the quality of the oil is to pour a little of it upon a plate or saucer, and apply a light to it. If it take fire, it is dangerous; but if it does not burn, it may be freely used. By purchasing the oil termed *Belmontine*, however, all danger is avoided, and a pure light is obtained at a very small cost, it being only one shilling and twopence per quart. A lamp of this kind may be placed as near the reflecting mirror as necessary, and may be raised or depressed by blocks at pleasure; while the glare upon the eye from the lamp itself may be easily avoided by suspending a shade of cardboard, or other similar material, in front of the eye-piece of the microscope. By turning the mirror about, the light is easily directed upwards through the transparent object, and regulated, either by slight eversion of the mirror, or by the use of a smaller stop in the diaphragm. If, however, it be desired (as is often the case) to examine an object which is impermeable to the light thus thrown up by the mirror, another method of illumination becomes necessary. For this purpose the *condenser* (fig. 4) is employed. It usually consists of a large plano-convex lens, and is sometimes mounted upon the microscope itself, being readily turned aside when not used, or towards the object, when required, by means of a joint or elbow. In the larger microscopes, however, this condenser, or bull's-eye, is mounted upon a stand (as in the figure), upon which it slides up and down, the glass being fixed upon a stem which is received in a tube, thus allowing of its being freely turned in a vertical direction; while the tube itself admits of a horizontal

movement upon the stand. The lens can thus be raised or turned in any direction, the intention being so to adjust it as to concentrate the rays in a focus upon the opaque object under examination. The plane surface should be nearest to flame.

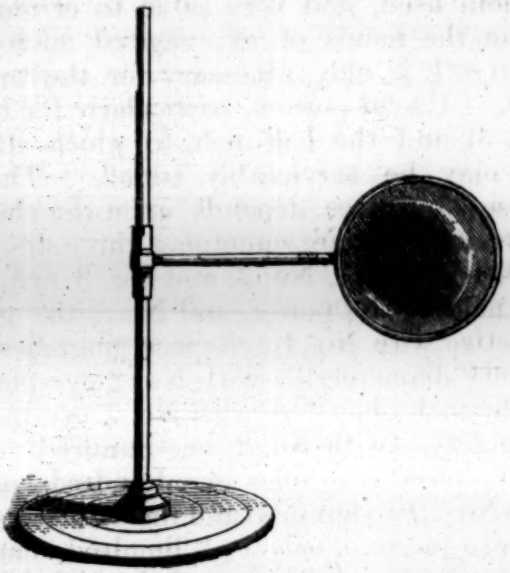


Fig. 4.

The position which the observer assumes should be one which is consistent with his own ease and comfort. In a constrained attitude he will soon tire, and physical fatigue will be followed by loss of interest and power of observation. The table, therefore, as well as the seat, should be regulated to meet his requirements, and such an obliquity given to the body of the microscope as may suit both. In looking for a long time down an instrument, the eye is liable to become fatigued, especially if the same eye is always used; it is desirable, therefore, that the observer should learn to use either eye at pleasure, and occasionally to change one for the other. But, since we are aware, from experience, that this is not always an easy matter, it will be well early to accustom oneself to keeping the unemployed eye open, by which means the fatigue arising from screwing it up with a constrained and constant effort, is avoided.*

The object-glasses vary in magnifying capability, and are hence called *powers*. Those whose *focal distance* is greater

* On no account should the observer continue the inspection if he feels pain or fatigue. Many microscopists have either impaired or destroyed their eyesight by too long continuance at the instrument, or by its too frequent employment.

than half an inch are usually termed *low* powers, and they are made as low as two inches (2-in.-power). If the focal distance is less than half an inch, it is a *high* power. Thus we have various powers, called respectively, *two-thirds* (of an inch), *quarter*-inch, *eighth*, and even *sixteenth*, though the last power is seldom used, and very liable to erroneous interpretation, even in the hands of experienced microscopists; and indeed the *eighth* is only necessary for the more recondite investigations. Useful powers, particularly for beginners, are the inch (fig. 3) and the half-inch, to which after a time the quarter-inch may be serviceably added. The magnifying power of these objectives depends upon the character of the eye-piece, of which there are sometimes three descriptions used, called respectively, No. 1, No. 2, and No. 3 eye-piece,—No. 1 having least magnifying power, and No. 3 the greatest. The two-inch objective with No. 1 eye-piece magnifies twenty times linear (or twenty diameters),—with No. 2 eye-piece, thirty-five diameters. The inch objective, with No. 1 eye-piece, magnifies fifty-five diameters,—with No. 2, one hundred. The half-inch with No. 1 eye-piece magnifies one hundred and twenty diameters,—with No. 2, two hundred and ten diameters. The quarter with No. 1 eye-piece equals two hundred diameters,—with No. 2, three hundred and fifty,—and the eighth, four hundred and fifty and seven hundred and sixty respectively.

In selecting one of these *powers* for the examination of any object, the observer must be guided by the *size* of the object. If of a considerable or appreciable size, it should be first scrutinized through a *low* power, which indeed may be found sufficient for the purpose, but if not, the next higher power may then be employed. If the object be very minute or imperceptible, the half or quarter-inch may be at once brought to bear upon it. And here let us remark, that in unscrewing and screwing on these objectives, some difficulty is apt to occur from the worm of the screw not easily slipping into the groove, particularly if the screw be a fine one; and the patience is sometimes severely tested by the delay. It often happens that this difficulty may be at once surmounted by giving the screw a turn in the wrong direction, by which means it is easily slipped into the groove, and may then be readily fastened.

To get the proper focus with a low power, all that is required is to turn the large milled-heads which move the tube of the microscope upon the rack-work, hence termed the *coarse adjustment;* but when high powers are used, more care is required in manipulation. The objective should be cautiously brought down by means of the coarse adjustment to within a short distance of the slide upon the stage, and then, with the eye at the eye-piece, and the finger upon the *fine adjust-*

ment, it must be moved backwards and forwards until the true focus is found, and consequent clear definition is obtained. But the fine adjustment has other uses besides merely *finding* the focus with a high power; with the finger upon it, and the eye at the microscope, the object should be well scrutinized, and each part or stratum of its thickness successively focused, the relations of these strata to one another only being satisfactorily determined while in the act of changing the focus. In using the *coarse* adjustment with high powers, the great thing to be avoided is heedlessly bringing down the object-glass upon the slide under examination, which an incautious turn of the screw may too easily accomplish, and which makes possessors of good microscopes very careful how they allow strangers to meddle with their instruments. The result of this accident may be either to break the glass slide on the stage, and totally destroy what is perhaps a valuable object,—or worse, it may result in a chip or scratch of a ten-guinea objective.

The young microscopist is very liable to fall into considerable errors of judgment while examining an object, particularly under high powers, arising from his inexperience and consequent inability to comprehend a distortion or recognize the truth. Nor need he lose courage at this, for experienced observers have fallen into similar errors of much more importance than any he is likely to make—errors which have given rise to false theories, and retarded the progress of science. Some of these errors, arising from optical appearances, can only be corrected by practice, or by the use of more complicated apparatus which the student will apply in the course of time. There are others, however, concerning which some hints may here be given. If the parts are not accurately in focus, the outlines may be either distorted, indistinct, or misrepresented. Lights and shadows may be completely reversed, as in the markings of the diatoms,* a circumstance which arises from the object itself refracting light. And the higher the power used, the greater is the liability to fall into this error. Sharply-defined black rings with a bright centre cause no little surprise to the beginner, which, however, are nothing more than minute *bubbles of air*. Oil-globules in water present much the same appearance; as also do globules of water, surrounded by a layer of oil. But if the object-glass be approached nearer to them, the water-bubbles and oil-globules get a darker centre, the water-globules in oil a lighter centre, and the reverse when the objective is raised. Such changes as these, as means of recognizing different substances often met with in the lower forms of animal and vegetable life,

* Lowly forms of life.

are useful lessons to the student. But for most errors of interpretation, the simplest remedy is the use of low powers until sufficient experience is gained to allow of higher powers being usefully employed.

In handling the eye-pieces and object-glasses, care should be taken to touch the glass surfaces themselves as little as possible, as they readily become dimmed by contact with the hands, or even by the moisture exhaled on too close an approach. A piece of wash-leather should be always at hand, as it is the best material for cleansing the glasses either from dust or moisture; and if any water is used, as in examining animals or vegetables in fluid, great caution should be exercised in keeping the object-glass dry; or if by accident it gets wetted, it should be wiped as soon as possible. This caution is particularly necessary when salt-water is used, and the microscope should be carefully cleansed of the least particle of it before being put away, otherwise unsightly corrosions, verdigris, and impaired action of the mechanical parts, will soon result. Indeed, every one who values his microscope will take the greatest care that it does not suffer from thoughtlessness, or inattention to such simple precautions.

In the foregoing sketch I have only alluded to such apparatus as may be regarded as essential to working with the microscope, but there are still many additional pieces which the student may with advantage add from time to time, as his experience or his wants increase. Of such accessory apparatus several are contrivances for improving the illumination, of which some are luxuries, and others are really useful, and even essential to the proper examination of special and peculiar objects by the experienced and professed microscopist. The *Lieberkühn speculum*, for examining opaque objects, and *Wenham's Parabolic Reflector*, for obtaining perfect definition under high powers, are examples of these. The *polarizing apparatus* I have altogether omitted, because any satisfactory description and explanation of it would have increased this paper beyond desirable limits; it can only be here stated that the polariscope is a useful addition to a microscope, particularly if it be chiefly used as a recreation, the beautiful chromatic effects which are produced by it being in the highest degree curious and fascinating; and even the scientific microscopist will sometimes find it of real service. *Micrometers*, glass slides with fine and regular lines for the measurement of minute objects—and finders, by means of which any special object of the minutest size may be at once placed under the object-glass, without the trouble of half an hour's search, are also useful additions. Other accessories relate to the examination of living objects. Usually, the prepared object is placed upon a flat glass; but if it is a minute living animal, it may be placed either on a thicker glass, hollowed out in the middle

for its reception, termed a *cell*, or in what is called a *live-box*, or *animalcule cage*, more particularly if the objects be swimming in water. For larger objects, such as zoophytes, or for showing the circulation in plants, a *glass trough* is necessary, which may be filled with water, laid upon the stage, and the object examined with a low power. For ordinary objects (not living), such as vegetable structures, parts of insects, &c., it is sufficient to lay them upon a flat piece of glass (or *slide*), and to place over them a round or square piece of very thin glass (made and sold for this purpose); and thus to examine them, either dry, or having first moistened them with a drop of clean water, which assists their transparency—care being taken to avoid air-bubbles between the two pieces of glass as much as possible, and to keep the upper part of the thin glass cover dry.

It now only remains to refer the student to some form of microscope which, not being too costly, will probably be within his means, but which at the same time shall be of guaranteed excellence, that he may not be tempted to waste his money upon inferior productions. In doing this it is manifestly invidious to single out any one name from a number of excellent makers, or to say which is the best of such manufacturers as Smith and Beck, Ross, Powell and Lealand, and others, when all are of such acknowledged merit. If we particularly allude to the first of these, it is because, besides the well-known excellence of their instruments, their less expensive microscopes appear to us to be adapted for the purpose we have in view. Their *Educational Microscope* is a portable, compact, and complete instrument, consisting of stand, mirror, spring-stage, condenser, diaphragm, two eye-pieces, and two objectives, viz., an inch, and a quarter inch, magnifying respectively, 55, 100, 200, and 350, linear. The price of this instrument is ten pounds; and for an additional five pounds, all the apparatus necessary may be secured, consisting of a Lieberkühn, parabolic reflector, polarizing apparatus, camera lucida (for drawing the magnified object), micrometer, live-box, and glass trough. This additional apparatus may be purchased at any future time. If the student is more ambitious, he may purchase the *Student's Microscope* with $\frac{2}{3}$ and $\frac{1}{5}$ objectives (reaching a linear magnifying power of 430), and apparatus complete, for £20. But for those whose means are more limited than either of these would imply, there is still an instrument, which may be within their reach, viz., *Field's Compound Microscope*, called the *Society of Arts Microscope*. This marvel of cheapness arose from a competition for an award offered by a committee of the Society of Arts, in 1854, for a low-priced compound microscope which should combine cheapness with the greatest degree of excellence. The award was made to Mr. G. Field, optician,

Birmingham, who is bound by agreement with the Society of Arts to keep the instrument always in stock, and supply any purchaser at once. It has two eye-pieces and two achromatic objectives, varying in power from 25 to 200 linear, a condenser on a separate stand, coarse and fine adjustment, stage-forceps, and live-box; and the whole, in a mahogany case, may be purchased for *three guineas*.

Finally, for further information upon the subject of the optical and mechanical principles of the microscope, manipulation, apparatus, collection and mounting of objects; and for an elaborate illustrated description of the microscopic forms of animal and vegetable life, we cannot do better than recommend Dr. Carpenter's work on "The Microscope and its Revelations" (price twelve shillings and sixpence) in Churchill's series of scientific manuals.*

* Useful little French microscopes for beginners with limited means may be purchased for ten and sixpence (walnut-wood case included); and for such also Dr. Lankester's little work, "Half-hours with the Microscope," illustrated by Tuffen West, F.L.S., will be found serviceable.—Ed.

CONTRIBUTIONS TO THE HISTORY OF THE ROTIFERA, OR WHEEL ANIMALCULES.

BY PHILIP HENRY GOSSE, F.R.S.

PART III.

THE BUILDERS (MELICERTADÆ).

NO aspect of natural history is more attractive, none at least takes a stronger hold on the minds of general readers, unsophisticated with mere technicalities, than that which presents the inferior creatures in the exercise of their manifold instincts. We are never tired of reading well-authenticated narratives of the manners of animals, their "sayings and doings;" their actions in ease and under the pressure of circumstances; their affections and passions towards their young, towards each other, towards other animals, towards man; their various arts and devices to protect their progeny, to shelter themselves from the weather, to procure food, to escape from their enemies, to defend themselves from attacks; their ingenious resources for concealment; their stratagems to find, to come up with, to waylay, to overpower their victims; their modes of bringing forth, of feeding, and of training their offspring; and a thousand other details of what is properly called their *history*.

What materials for reflection, what incentives to praise—adoring, admiring praise—of Him who is *maximus in minimis*, do we discover in a bird's nest! How varied, how incongruous, in many cases how apparently unsuitable are the substances used; how few and simple are the implements employed:—

"No knife to cut, no bodkin to insert,"—

yet how perfectly is the work performed, how completely is the object attained! So compact, so firm, so warm, so tight, so well secured, so well concealed!

The beaver—which associates with its fellows, to hew down with patient toil the massive trees, and then forms, with admirable

engineering skill, strong dams across rapid streams, and builds covered houses which contain dwelling-rooms, sleeping-rooms, nurseries, and larders, communicating with one another, and covered by a common roof—must ever be surrounded by a halo of romantic interest, scarcely diminished by the slight pruning which the accuracy of modern research has inflicted upon older exaggerations.

How marvellous are the instincts of the termites or white ants of the tropics, which, uniting in armies of myriads, build great stony structures of cement manufactured by themselves, including various chambers and galleries, carry arched tunnels under ground, make long covered ways, and throw light but substantial tubular bridges across hollows!* And how additionally marvellous is the marshalled order in which these hosts are arranged; not forming a promiscuous multitude, but divided into ranks, as strongly defined and as permanent as are the castes of India or Japan;—the royal pair nourished with loving care, and housed in capacious domed apartments; the soldiers ever ready for warlike attack or defence, but never making the slightest attempt to build or repair; the labouring millions unfit for battle, but ever ready with their assiduous skilled labour to erect or enlarge or repair the common edifice, or to collect food for the common sustenance!

Scarcely less curious, and more celebrated, are the social and architectural instincts of the hive-bees and the paper-making wasps. These, though they do not display the same elaborateness of class-division as the termites, yet have claims to admiration peculiarly their own, in the perfect mathematical regularity with which they form their dwellings, and the materials which they employ in the construction,—wax in the one case, paper in the other, each substance being collected in a crude state, and then elaborated by the insects themselves.

In the woods of Southern Africa the traveller meets here and there with trees, the trunk and principal branches of which are inclosed in a vast dome of thatch, suggesting the thought that a large barn had once stood on the spot, but that a tree had grown from the area through the roof and lifted it from the walls, which had then fallen and disappeared. It is the residence of a colony of birds,—the sociable grosbeak—which, five hundred to a thousand in number, build their nests in crowded proximity, and protect the whole with this well-compacted thatch of native grass.

Yet another species of the same tribe of birds,—the pensile grosbeak,—inhabiting the same regions, associates in like multitudes, but builds habitations of more elegance, which we may

* Smeathman, *passim*.

liken to detached villas rather than to the crowded houses of a town. For the nests of these little birds are long purse-like structures, curiously woven of reeds and grass, in the form of long bags, with the entrance-hole at the lower end, suspended from the projecting boughs and twigs of some wide-spreading tree, generally over a river or other water. Several hundreds of these "tree-rocked cradles," all separate, though in close proximity, have been observed depending from the branches of one tree.

Two forms of instinct are presented to us in these examples, which, though often conjoined, are yet distinct. There is the constructive instinct displayed in strong development, and there is the instinct of association. In multitudes of cases we find these two tendencies acting separately. If there are social bees and wasps, there are solitary species too, which build their habitations without seeking the solace of companionship. The squirrel builds its little drey in the pine-tree, and the bottle-tit weaves its beautiful nest below him, without the slightest wish on the part of either to have any companion but his own mate and offspring. On the other hand, there are numberless examples of the social habit with no special constructive power. The wild dog hunts in packs; the gannet and the gull congregate around the precipitous cliffs; the tiny gnats play on twinkling wings, in clouds, under a December sun;—but there is no particular tendency to prosecute the builder's art in either.

It is difficult to understand this tendency to associate without attributing to the animals which display it something analogous to human feelings and affections. In some cases, it is true, we can trace an utilitarian end more or less obvious. It is evident that the structure of the termites could not be built without concert; the isolated beaver would be seemingly far less comfortably housed and far less efficiently protected if he had not the advantage of the dam and house, which yet he could not achieve alone; though isolated beavers, "old bachelors," are found on the European rivers. The sociable grosbeak, too, derives additional protection from the massiveness of the thatch which the united powers of the colony produce, at least we may suppose so: but what is gained, beyond the amenities of companionship, by the pensile grosbeak's choosing to hang his separate bottle-nest on the same tree and on the same twig as his fellow? The pack of wild hounds may run down a stronger and a swifter prey than a single dog could master; but what of material prosperity does the little winter-gnat gain by dancing in company with a thousand more, which it would lose if it had chosen to frisk alone a dozen yards off, in the same air and under the same sunbeam?

Surely there must be a consciousness of pleasure derived from the recognized proximity of others of the same kind, quite independent of the mere material welfare of the individual; and if this inference be unavoidable, then we must admit, even in creatures so far removed from man as these tiny invertebrata, the implantation of sentiments and feelings of like nature to those which in him we distinguish as moral,—differing not in kind, but only in degree.

There is a not unnatural reluctance in our minds to admit the existence of such feelings in the more minute creatures, even when we have no hesitation in attributing them to the dog, the horse, or the elephant. It does certainly strike one as more wonderful to find mental and moral emotions associated with a tiny insect-body and a homogangliate system of nerves; but we may discover even in such a combination new proofs of the infinite resources of the unbounded God, to whom nothing is great, nothing small. "If," says Basil of Cæsarea, "we speak of a fly, or a gnat, or a bee, our discourse must demonstrate the power of His hand who created it. The skill of the artificer is most manifest in His most minute works; and He who stretched out the heavens and excavated the seas, is the same Being who has perforated the sting of the bee as a passage for its venom."

The class of animals of which I am treating in this series of papers is composed of individuals which are far more minute than even the smallest of those which we have just been noticing. Not one of them is large enough to be detected by the unassisted human sight; or, if there is an exception, in strict literal truth, to such a statement, it only amounts to this, that when held up in the most favourable position to the light, the skilled and disciplined eye might just discern a speck of matter which microscopic examination would prove to be a *Stephanoceros*. Can it be within the range of possibility that instincts and faculties kindred in character to those above described exist in an atom of life, several hundreds of which, if ranked side by side, would comfortably pack within the inch-measure of an ivory scale? Can mental or moral perceptions and sentiments find their seat in such a being as this? Yes, there is good reason to conclude that they may. Absurd, and even ludicrous as the assumption may appear to some minds, I shall presently adduce some curious facts, which as conclusively testify to thought and feeling in the soul (ψυχὴ, *anima*) of a Rotifer unappreciable to the human sense, as do the social and constructive instincts in that of a grosbeak or a beaver.

Let us now consider another family of this class ROTIFERA. We may distinguish them as BUILDER ANIMALCULES, and, selecting a scientific family title from that genus in which the pro-

minent character is most fully developed, call them the family MELICERTADÆ. Like the Flower Animalcules, they live in tubular cases, which are formed by an exudation from the surface of their bodies, and which are moulded into shape by their movements on the foot as a pivot. In one or two instances, indeed, the enveloping case seems wanting; but, as we have seen in some of the Floscules, that this defence is occasionally evanescent, it may be that in these it is so slight as to have escaped detection. Their bodies are nearly cylindrical, abruptly attenuated to a long and slender foot, the base of which is, after early infancy, permanently attached to some fixed substance, such as the stem or leaves of water-plants. In one instance, however, the feet of many individuals are attached to each other, and thus a radiating sphere of animals is composed which swims at large. This I shall describe more particularly presently.

Thus far, the Crown Wheel and the Floscules might have been united with this family; but we now come to important differences whereby it is distinguished from those genera. We have seen that they have a disk which runs into five points, beset with long bristles, only occasionally vibratile. Our present subjects have disks which do not run into points, whose divisions are twofold and fourfold, and whose margins are uniformly clothed with short cilia, which vibrate without intermission (during expansion), with a succession of rhythmic waves whose appearance to the eye is that of an endless rotation of toothed wheels.

Their most important distinctive character, however, though not so obvious as the one just mentioned, since it requires high powers of the instrument and practised skill in the observer to make it manifest, is the form of that organ in the midst of the upper body, which has been generally called a gizzard, but which I have reasons for considering as the true mouth. To describe, so as to be intelligible, an organ so complex as this, is difficult, but with the aid of the following illustration I hope to give my readers some idea of it. Take a rather pointed apple and cut it through from the point to the base, leaving the short stalk attached to one half. Choose this half (rejecting the other), and again split it through the middle, doing it carefully, so as not to separate either from the stalk which just holds the pieces together. Pull the tips slightly apart and lay them down on their rounded surfaces, the flat sides uppermost. Now take six pins, and bending them all into an arch, lay three across each division of the semi-apple, so that they lie parallel, a little apart from each other, the points of one set just meeting the points of the other, if the two divisions be pressed together. If the pins could be slightly sunk into the face of the apple, it would be so much the better. The pins

ought to be long enough for at least half their length to project beyond the outside of the apple, and if their heads (or projecting ends) could be now embraced, each set of three, by a bow-shaped piece of wax, about as large as one of the divisions of the apple, without disturbing the arrangement already described, you would have a very fair representation of the parts of the mouth in this family.

There is, however, one element more,—the *mastax*. You must imagine (for I cannot suggest any device for really representing this, so as to retain the form for even an instant) three globules of transparent substance—really it is muscular tissue—surrounding the whole apparatus, one on each side, containing the apple, pins, and wax of that side, and the third surrounding the points;—the globules united and flowing into one at their mutual contact, but preserving the three-lobed character of their outline. Remember that, this envelope being composed of living muscle, the contained parts have the power of motion, without destroying its continuity, though slightly changing its outline.

Now, to understand the action of this curious mouth and jaws, let us further suppose the whole apparatus carefully transferred to the interior of a confectioner's show-glass, the cylindrical form of which will well enough represent one of our little friends, the Builder Animalcules. Consider the three-lobed mass suspended in the cylinder near the top, almost in the centre of the diameter, the cut faces of the apple upwards and horizontal. The top of the glass cylinder is covered with a flat piece of parchment, which expands far beyond its diameter on all sides, and whose edge is more or less cut into rounded lobes. In the middle of this sheet there is a hole or tube which leads down to the apparatus; or perhaps it may be more correct to consider the parchment as forming a wide and shallow funnel, with an abrupt tube, which opens into the muscle-mass, just over the point of union of the jaws, *i.e.*, the stem of the apple; while from the under side of the muscle-lobe that embraces the points another tube leads downward to the stomach.

Of course all this is but a rude and homely comparison; but it will probably make the whole process of the reception of food in these creatures, with the uses of the various surrounding organs, far clearer than any amount of mere technical description, however accurate, could do.

The action, then, is as follows:—The edge of the expanded disk, which I represent by the parchment funnel, is, as I have already said, crowded with vibrating cilia, which produce strong currents in the surrounding water. As the ciliary beatings are all in one direction, the impulse given to the water is circular (we may consider it such at least), and thus a whirlpool is formed, the

centre of which is the lowest part of the funnel. By this contrivance, then, there is a constant rush of water down the tube, carrying with it whatever of floating atoms it may hold in suspension. These are poured down upon the lower jaws (*rami*) at the point where they are hinged together, as represented by the stem of the semi-apple, a sort of valve in the tube shutting out whatever would be hurtful or unfit for food. They are then spread along and between the jaws—the apple-quarters,—which are vigorously opened and closed alternately, with a rapid rolling movement. Thus the points of the upper jaws (*mallei*), represented by the two sets of pins, working towards each other, bruise and pierce the *infusoria*, or the atoms of organic matter, poured along the faces, and gradually grind them down, while the result passes off by the lower tube (*œsophagus*) into the stomach for digestion.

I have dwelt the longer on this matter because the same illustration serves to explain the process and organs of the reception of food, not only in this family, but in almost all the ROTIFERA. The subject is full of difficulty and obscurity to beginners, and it was not till after years of laborious study that I myself succeeded in elucidating the details; but once mastered, a large part of the structure and economy of these little creatures is intelligible. After the action of the ciliary "wheels,"—which is sure to be the first thing that arrests the attention and wonder of the beholder, and which is in no species seen to more advantage than in those of the present family,—the movements of the mouth (or *gizzard* of the older writers) attract notice, and we wish to know the meaning of them; the form and character of the very complex organs inclosed in this curious bulb, their connexion with the surrounding parts, and the object of their almost incessant vigorous working. I may find occasion, hereafter, to show by what steps I have arrived at the conclusion that this apparently *internal* organ, the so-called *gizzard*, is a real proper mouth, and its indubitable analogy with the parts of the mouth in INSECTS. In the forms we are now considering it is so much disguised and modified that I could scarcely hope to make myself understood; but we shall come to species by-and-by in which all the parts described above are readily identified, but so altered in shape, and especially in position, that we shall see at once that they form two pairs of real jaws, very closely resembling those of a biting insect. For the present I content myself with hoping that by the aid of apple, pins, and wax, the reader will have no difficulty in forming a tolerably vivid idea of the organs as they appear in this family, and a correct notion of what are their functions, and how performed.

The family before us* comprises animals which are placed by Ehrenberg in nine genera, named *Ptygura, Œcistes, Conochilus, Megalotrocha, Lacinularia, Tubicolaria, Limnias, Melicerta,* and *Cephalosiphon.* Each of these genera, however, contains but a single species; and I am much inclined to reduce the whole nine to two. Thus, *Ptygura, Œcistes, Tubicolaria, Limnias, Melicerta,* and *Cephalosiphon* seem to me to be only so many species of one genus; while *Megalotrocha, Lacinularia,* and *Conŏchilus* constitute another.

To the former of these I propose to appropriate the name *Melicerta,* to the latter that of *Megalotrocha.* They may be distinguished by the circumstance that in the former the individuals are always solitary; in the latter they are (in adult age) aggregated by mutual adhesion into somewhat spherical masses composed of many animals radiating in every direction from a common central point of adhesion. These compound spheres are either free or fixed.

The genus *Melicerta,* as so enlarged, or the Tube-dwellers proper, have the front or upper part of the body capable of being turned in upon itself, and concealed with purse-like folds, and of being expanded at the pleasure of the animal into a disk, which is usually much wider than the diameter of the body. This is either flat or in the form of a very shallow funnel. Its outline may form either a simple circle, as in *M. ptygura* and *M.* (*Œcistes*) *crystallina;* two circles united at one point, as in *M.* (*Limnias*) *ceratophylli;* or four sinuous lobes, more or less developed, as in *M. cephalosiphon, M.* (*Tubicolaria*) *najas,* and *M. ringens.* In each case there is, according to Professor Huxley, a double edge to the disk; of which the subordinate one is placed on the under side, and a little within the line of the principal. The former is fringed with very minute cilia; the latter with long and strong ones, whose vibratile waves form well-marked opaque spots which ever run along the margin. In each example, even where the circle of cilia is simple and appears in some aspects to be complete, it

* As I propose to subdivide the class ROTIFERA in a mode differing from any as yet published, I add here the technical characters of this family.

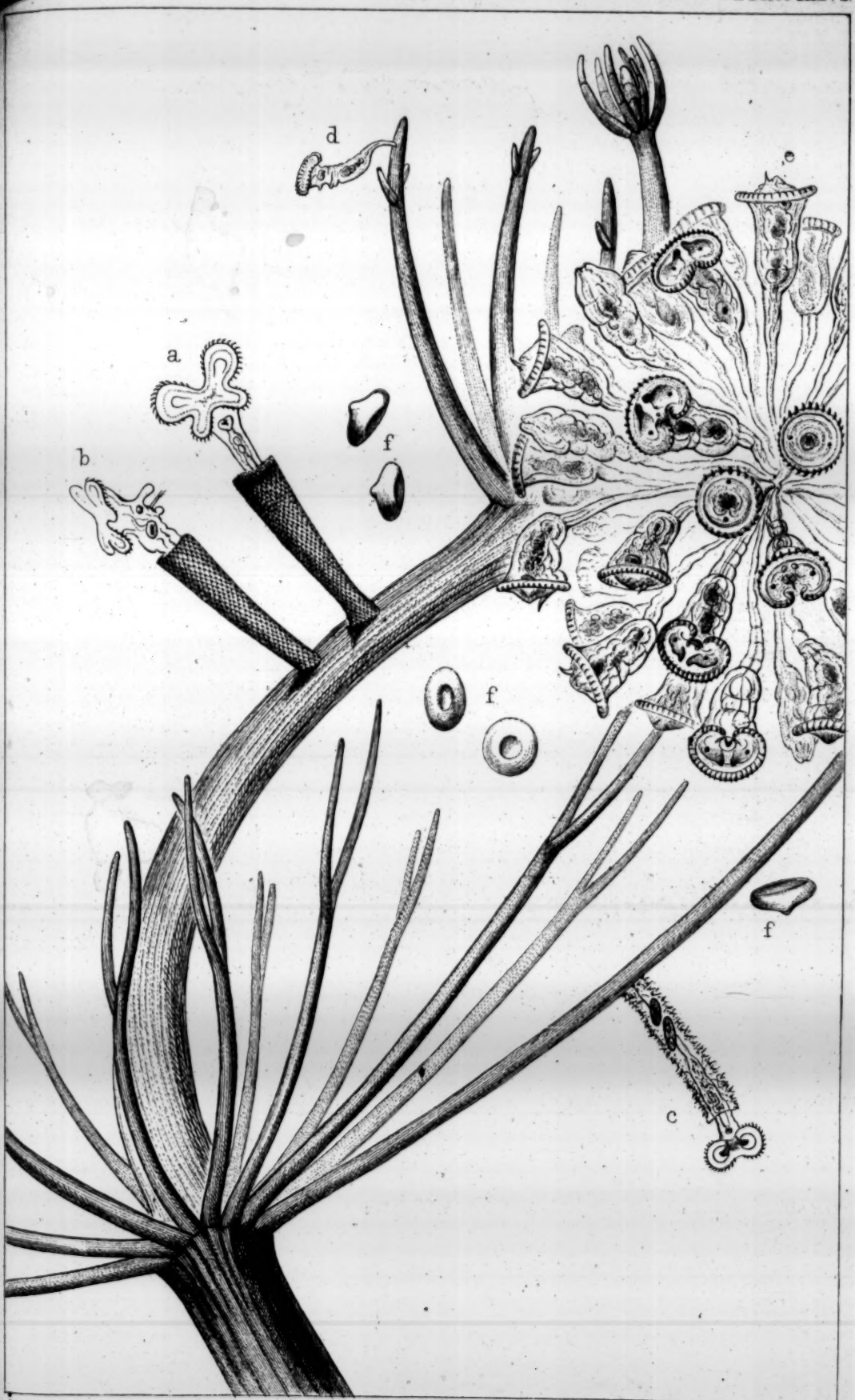
Melicertadæ.—Animal free in infancy, attached in adult age either to some foreign fixed body or to others of its own kind; inhabiting (in most cases) a gelatinous tube which is excreted from the skin. Front expanded into a broad disk, never five-pointed, but with a tendency to form two or four rounded lobes, furnished with ordinary vibratile marginal cilia in uninterrupted series. Jaws inclosed in a three-lobed mastax, each malleus soldered to the ramus of the incus, and together forming a quadranti-globular mass. Body sub-cylindrical, abruptly attenuated to a long, transversely wrinkled foot, neither telescopic nor retractile.

is really broken at the hinder part, where the curved lines turn short upon themselves.

It is a very charming sight, especially to a tyro in microscopy, whose attention is riveted and his wonder excited by the spectacle, to behold one of these animals in full play under a good instrument. Probably, when he first sits down to his observation, he discerns nothing but an opaque or semi-opaque tube standing up like a tall chimney, a little widening upward; for the timid little tenant, alarmed by the shaking of the table produced by the observer's movements in sitting down and preparing, is shrunken down out of sight into his snug castle. In a few moments, however, something peeps from the top; perhaps it is a simple rounded mass of crystal flesh, as in *cerato-phylli;* or the long antennal tube of *cephalosiphon* thrust out by jerks, and vigorously thrown to and fro; or the two incurving horns of *ringens* slowly protruding.

Suppose it is the last-named species, the most attractive of all, perhaps I may say the most interesting of the entire class of ROTIFERA. As the rounded mass of translucent flesh still protrudes, crowned by its two horns like the spines of a rose, two other organs suddenly appear, stretching out from another part of the convexity, two long clear tubes, extending horizontally, one on each side, which are the feelers or antennæ. Now a quivering is discerned in the interior; and in a moment the extremity opens and unfolds into four wide rounded flat lobes, like the petals of a transparent flower. The plane of this flower-like disk is not horizontal, but more or less oblique, sometimes approaching to perpendicular, and the two petals which are the highest are considerably larger than the two that are lowest; the former being the fore, the latter the hind pair. (See Plate XXVI., figs. *a*, *b*.)

No sooner is this lovely flower in full blossom than you perceive the curious furniture of its margin. You cannot help perceiving it; your eye is instantly drawn from every other part to gaze upon this wonderful sight. There is seen a set of black beads on the very edge, each divided by a narrow interspace from its fellows, which are engaged, without a moment's interruption, and with the most perfect regularity, in chasing each other all round the margin. Round and round they go, into the sinuosities, over the projections, with a steady majestic swiftness which is quite entrancing to behold. If you suppose the crown-wheel of a watch to be made of glass, and the teeth to be painted black, you would have in its movement an appearance somewhat like that of one of the simple disks of the genus, such as that of *crystallinus;* but in this species the case is complicated by the wheel being four-petalled instead of circular. Again, however, you see that the disk itself does not



P.H. Gosse, ad viv. Tuffen West, sc.

W. West, imp.

Builder Animalcules.

rotate, but the black teeth only, and these change their form in certain parts of their revolution, becoming confused, and then again bursting into distinctness.

It is almost impossible to believe that you do not see an actual rotatory movement of the parts, that the black spots are not real solid organs, they are so palpable, so well-defined. Yet it is manifest on a moment's reflection, that such a motion, continued without intermission for hundreds of revolutions, would be perfectly incompatible with the necessary conditions of an animal body. In reality you do not see parts at all; the black spots are only waves in the cilia: an optical illusion produced by the cilia being brought momentarily closer together at certain regular points, causing opacity, and alternating with correspondent separations, causing transparency. These *waves* run ceaselessly round, but the cilia themselves do not change their place: they merely bend and straighten themselves in rhythmic alternation.

After we have somewhat satiated our sense of sight with this beautiful spectacle, we have leisure to look at the tubular case in which the animal dwells. It is not, like that of the Crown-wheel and the Floscules, and, indeed, like those of most of the species of this family, transparent and simply gelatinous, but quite opaque; so that, with the exception of those upper parts that are protruded from its protection, the body is altogether concealed. We can discern that its surface is composed of round bead-like objects set in a regular symmetry in a kind of mosaic pattern, and that these globules are of a dark-reddish or yellowish-brown hue. In truth, the foundation of this *Melicerta's* case is a tubular layer of gelatinous mucus, thrown off from the surface of its body, tenacious and transparent, as in other kindred cases, as may be distinctly seen in the creature's infancy, when it begins to construct its house; but there is superadded to this an outer layer of stiff globules, which are imbedded individually in the gelatinous substance, imparting to it firmness and opacity. The preparation and deposition of these building-stones form one of the most interesting chapters in the history of the class.

In carefully watching your specimen, it may be that you will be fortunate enough to detect him in the very act of building his house,—a process which is not performed all at once, but step by step, at long intervals, a little at a time, as the owner's growth requires commensurate elbow-room. Now, as he is the judge of this necessity for labour, we cannot force him to work when he has not a mind to it; and so you may watch a number of individuals, and tantalizingly fail in ever seeing the process. But it may be that you will be more fortunate, as I have been

repeatedly. Lest, however, you be unsuccessful, I must describe to you what takes place.

If you get a sight of the animal, while fully expanded and rotating, *sidewise* (as shown in fig. *b*), you will see that the front outline of the head descends from the sinus between the great upper petals, and follows an irregular curve to a rounded projection which I have familiarly called the chin. Below this there is a considerable recess, at the bottom of which we may discern a tiny cup-like cavity, midway between the two antennæ. I have indicated it (in fig. *b*) as seen through the transparency of the flesh, which projects a little on each side of it.

Carefully marking now the course of the great ciliary wave on the margin of the petals, you will observe a certain deviation from its circular course. But this will be made much clearer by an ingenious device, which will afford you pleasure on several accounts. Rub a cake of water-colour carmine on a palette, and with a sable pencil take up a minute portion, and diffuse it in the water of your animalcule cell, which contains your *Melicerta*. Put on the glass cover, and observe again. As soon as the little animal recommences its ciliary gyrations, the dark-red atoms of pigment are put in motion, and you see at once that you have obtained a very important aid in distinguishing the currents. If you have not diffused too much paint, the animal will continue its rotations without inconvenience, and the transparency of the water will not be materially affected. The result is immediate and striking. Particles of red pigment are drawn from all quarters toward the disk, on approaching which they arrange themselves in a wide band, which is hurled along in directions parallel to the sinuations of the margin, keeping a uniform distance just outside the ever-chasing black wave-specks. This band of red dots circles ceaselessly round and round, but at the great frontal sinus a portion of them is ever drawn off from the general course, and driven along the irregular front line, which you see in the side view (fig. *b*), toward the projecting chin. The cloud of dots rapidly runs on round the tip of this organ, rushes under it, still following the outline, till it terminates in the tiny cup beneath, which I have already mentioned. In order now to pursue the observation with advantage, we must get a sight of the animal in front, so as to have a direct view of the little cup. This would be by no means a chance scarcely to be hoped for, for while the *Melicerta* is engaged in building she very frequently turns herself from side to side, so as to bring different aspects of her person before the eye. Having obtained such an aspect, you see that the interior of the little cup is beset with very minute cilia, which maintain a rapid rotation. The frontal current,

then, drawing off through the great sinus a portion of the circling cloud of pigment, deposits it atom after atom in the little cup-shaped receptacle until it is full. Meanwhile the accumulating contents have been, and are still, whirled round and round within the cup by the action of the interior cilia, which process, probably aided by the secretion and admixture of some animal glue, gradually consolidates them into a tiny globular pellet, whose shape is moulded by that of the cup. Suddenly now we see the animal bend itself forward till the cup is brought into contact with the upper edge of the case; it remains so bent for an instant, and then as quickly resumes its upright posture. *The cup, however, is now empty;* for the consolidated pellet, a little globule exactly agreeing in shape and size with those of which the case is made up, but differing from them in being of a deep-red hue, *has been left on the edge of the case,* where it firmly adheres. The process under these circumstances occupies from two and a half to three and a half minutes; at the end of which interval another pellet is completed and instantly deposited. So the work goes on; the animal occasionally shifting partly round, depositing two or three at one spot, then a few at another part of the edge, not proceeding regularly along the horizontal course, so that the unfinished edge of a case is always uneven; while yet, on the whole, the edifice heightens with pretty fair equality. The profusion of solid matter in suspension, available for the animal's purpose, causes the process of manufacturing these bricks to be much more rapid than it would be under ordinary circumstances. The material commonly collected appears to be the organic matters which form the residua of digestion, with which their colour well agrees; and these are doubtless obtainable only at intervals and in small quantities.

Thus we have here an animal of invisible minuteness which displays more than merely constructive powers. It had been surely a most interesting phenomenon if the tiny creature had formed its case, like the caddis-worm of our brooks, out of ready-made materials which it picked up and appropriated, and no more. But, in addition to this, there is the instinct of fashioning the crude materials into solidity and shape,—a true manufacturing process. Here is not only a clever architect and bricklayer who builds his symmetrical house, brick by brick in regular courses, cementing each with a mortar which, like the Aberthaw lime, sets and hardens under water; but an artisan who collects various sorts of crude substances, and, with the aid of certain machinery peculiar to himself, consolidates, compresses, and moulds them into bricks of regular form and perfectly uniform dimensions, before he makes use of them.

I will take the liberty of repeating here some reflections,

which I have made in another place, on the psychical phenomena legitimately inferrible from this minute animal's proceedings :—

"It is impossible to witness the constructive operations of the *Melicerta* without being convinced that it possesses mental faculties,—at least if we allow these to any animals below man. If, when the chimpanzee weaves together the branches of a tree to make himself a bed; when the beaver, in concert with his fellows, gnaws down the birch saplings, and collects clay to form a dam; when the martin brings together pellets of mud and arranges them under our eaves into a hollow receptacle for her eggs and young,—we do not hesitate to recognize *mind*—call it instinct or reason, or a combination of both,—how can we fail to see that in the operations of the invisible animalcule there are the workings of an immaterial principle? There must be a power to judge of the condition of its case, of the height to which it must be carried, of the time when this must be done; a will to commence and to go on, a will to leave off (for the ciliary current is entirely under control); a consciousness of the readiness of the pellet, an accurate estimate of the spot where it needs to be deposited (may I not say also a memory where the previous ones had been laid, since the deposition does not go on in *regular* succession, but here and there, yet so as to keep the edge tolerably uniform in height?), and a will to determine that there it shall be put. But, surely, these are mental powers. Yet mind animating an atom so small that your eyes strained to the utmost can only just discern the speck in the most favourable circumstances, as when you hold the glass which contains it between your eye and the light, so that the ray shall illumine the tiny form while the background is dark behind it!"

This prettly little builder is very common on most of our pond-weeds, and when it does occur, a good many are generally found in close proximity.* I have had them swarming to such a degree that sixty or seventy were crowded on a single small leaf. An adult will measure 1-20th of an inch in height, of which the case may be 1-24th of an inch. Such a case contains about thirty or thirty-five horizontal rows or courses of pellets. Each pellet is surrounded by six others; they are set in uninterrupted perpendicular lines; but those of one horizontal row are made to alternate with those above and below it, just as bricks are ordinarily set in a wall. Each naturally-made pellet, exa-

* Dr. Mantell ("Thoughts on Animalcules," pl. iv.) has figured an adult *M. ceratophylli*, with seven young, each with a well-formed case, adhering to various points of the parental case. I have never met with such an example as this, but have seen one case attached to an older one.

mined separately, is of a yellowish or olive colour, composed of granules. Old cases have their surface studded with minute parasites, both plants and animals, as *Confervæ*, *Diatomaceæ*, *Podophryæ*, and other extraneous matters, even to the summit. By picking the case to pieces with the points of needles under a low-powered dissecting microscope, I have been enabled easily to extract the animal; it is often hurt by the process, but generally it is sufficiently whole to display the internal organization, which, owing to the opacity of the case, cannot otherwise be discerned. It exhibits no peculiarity, however, that calls for notice here.

The eggs are laid within the case, as I have described and figured in the Floscules (*vide supra*, p. 166, Plate IX.); nor do they importantly differ from those of that genus, except in their shape, exhibiting a longer ellipse. This lengthened form appears to be characteristic of *Melicerta* (at least I have found it in all the species whose eggs I have examined), and to be peculiar to it.

On certain occasions I have, however, found eggs of a very different figure and appearance, which I have reason to believe would have produced male animals, probably of peculiar form. On these eggs, and on the development of the young, I have communicated some observations to the Microscopical Society, which may be of sufficient interest to be repeated here.

Opening one or two cases of *Melicerta ringens*, I freed one and another very curious egg-like bodies, not symmetrical in shape, being much more gibbous on one side than the opposite, and measuring 1-150th by 1-260th of an inch. Each was encircled by five or six raised ribs, running parallel to each other longitudinally, somewhat like the ribs (*varices*) that adorn the beautiful shells known as wentle-traps. Viewed perpendicularly to the ribs, the form is symmetrical—a long, narrow oval. The whole surface between the ribs appeared punctured or granulate, and the colour was a dull brownish yellow. Under pressure this egg was ruptured, and discharged an infinity of atoms of an excessive minuteness, but every one of which, for a few seconds, displayed spontaneous motion. Their whole appearance, and the manner in which they presently turned to motionless disks, were exactly the same as of the *spermatozoa*, which the male eggs of other ROTIFERA contain, except that these were more minute than usual.

From another case I extracted an egg of the ordinary form and appearance. It was very long in proportion to its width, measuring 1-145th by 1-390th of an inch. The contained embryo was well advanced; two red eyes were plainly seen, both by reflected and by transmitted light; the mouth (*mastax*) was transverse, very large in proportion, and the jaws worked

vigorously; a little opaque body, white under sunlight, was in the posterior part. This embryo died without being hatched.

I found a young one, about half-adult size, attached by the base of its tube to the side of the tube of an adult, near the summit of the latter, so as to project obliquely upward. This specimen, which was perfectly formed, gave me an excellent opportunity for observing the ventral aspect and the dorsal. It had two red eyes, one placed near the base of each larger petal. I have never discerned the eyes in adults. It was very energetic, diligently engaged in manufacturing the pellets and laying them on. It seems that the action of the pellet-cup is voluntary, and not always coexistent with the passing of the ciliary current over the chin. The animal frequently makes abortive efforts to deposit a pellet, and sometimes bends forcibly forward to the edge of the case before the pellet is half formed.

This specimen lived with me fourteen days after I discovered it, active and apparently healthy, till it suddenly died. During the whole time it scarcely increased in size, nor did it add any pellets to its case, except a few in the first day or two. The eyes remained distinctly visible to the last. It would be interesting to know the natural period of life in these little creatures.

On another occasion, looking into the animalcule-cage, in which were several cases, I found a young one swimming rapidly out in a giddy, headlong manner. I believe it was just hatched. Its form was somewhat trumpet-shaped, or like that of a *Stentor*, with a wreath of cilia around the head, interrupted at two opposite points. The central portion of the head rose into a low cone. After whirling about for a few minutes, its motion became retarded, and it began to adhere momentarily, and to move forward by successive jerks, not more than its own length at once. The period of its remaining stationary increased, so that I several times supposed it had taken permanent position, when some shock or alarm would send it off for a little distance again. At length, about an hour after I first saw it, it finally settled, adhering by the foot to the lower glass of the box. After a few rapid gyrations upon the foot as a pivot, it became vertical. The form of the adult was now distinctly assumed; the four petals of the disk were well made out, though the sinuosities were yet shallow: the antennæ at first were only small square nipples, but soon shot out into the usual form; the ciliated chin was distinct, as was also the whirling of the pellet-cup immediately beneath it. A pellet was quickly formed, and instantly deposited at the foot — the first brick of its house; the same operation was repeated with energy and

industry, so that in a few minutes a row of pellets was seen, forming a portion of a circle around its foot-base. When two or three rows were formed, I took occasion to measure the time of their construction: one pellet was deposited every minute with great regularity. I mixed a little carmine with the water: the result was beautiful; for the dark torrent that poured off in front, and the appearance of a rich crimson pellet in the cup, were instantaneous. Yet the imbibition seemed deleterious; for the animal would withdraw itself suddenly, after a revolution or two, and presently retired sullenly, having laid five or six carmine pellets, whose deep tints made them conspicuous on the pellucid yellowish ones. Some three hours after, I saw that no more had been laid. But in the course of the night the case was considerably increased with carmine; the part so made was much less regularly formed of pellets than that composed of the natural material; for the red portion was all confused and blended, as it were, into a mass, without distinction of pellets, though retaining the tubular form.

A large one, whose case had become accidentally injured near the base, so as to be slit for some distance up, protruded itself through the opening, remaining still attached by the foot. It did not enter again, but continued for several days, carrying on all the functions in the healthiest manner, exposed. It frequently made pellets, but these were never deposited, but allowed to wash off into the water; nor was any attempt made to construct a new case. A half-grown one, very active, that was near, deposited pellets only rarely,—eight or ten in several days; whence it appears that this process is quite voluntary; indeed, if it were not so, so rapid is the formation, that the tube would be increased beyond all bounds in a very brief period of the animal's life.

Of the other species of this genus I shall not here say much. *M. ceratophylli* (see fig. *c*) inhabits a case which is more or less of a yellowish-brown tint, but is sufficiently translucent to allow the body and foot of the animal to be discerned through it, and is never strengthened with anything corresponding to its sister's ingenious outer wall of self-made bricks. It has not attained to that effort of *mind;* perhaps I might say, it has not sufficient *head-piece;* for if you look at its coronal disk, you will see that it is only half as much developed as its sister's; for, whereas that has four petal-like lobes, this has but two. These two form perfect circles united at the central point of contact; or the whole outline may be designated a figure of 8. From its symmetry it is a very elegant object, especially when the ciliary waves are rotating. The gelatinous case in this species is generally much beset with

Diatomaceæ, Confervæ, &c., which are entangled in the viscid substance.*

M. najas I have never met with. Ehrenberg describes it as having a disk divided into two lobes, each of which is slightly indented, so that it is four-petaled, but less distinctly than in *M. ringens.* In other respects it seems to present no peculiarity worth notice.

M. cephalosiphon has a disk of much the same form, the sinuous indentations being even less marked. This has lately been discovered near London in abundance on the leaves of the *Anacharis alsinastrum,*—that recently-introduced ditch-weed, which is fast usurping the place of all other aquatics in our ponds and rivers. Mr. Slack, in his "Marvels of Pond Life," p. 149, first figured it, and has since, by supplying me with specimens, kindly enabled me to describe it more fully.† The species dwells in a tall but narrow case, of so dark brown a colour as to be quite opaque. Its texture is coarse and rough, but it is not made up of well-fixed symmetrical pellets, as is that of *M. ringens.* The most remarkable peculiarity of the species is a single antenna (each of the preceding species has a pair of these organs), which is of great length, forming a transparent tube, furnished at the tip with a tuft of diverging bristles. This organ is evidently used as a feeler; and it is highly interesting to see, when the animal is emerging from its case, how this long antenna is thrust out first, and is jerked with great vigour and suddenness from side to side, poking here and there, as if to ascertain that the coast is clear for the disk to be protruded and to commence its ciliary operations with security against danger or interruption.

M. crystallinus, if I may judge from my own observations, and I have seen it in great numbers, does not deserve the specific name which Ehrenberg applied to it. He describes the translucency of the case to be such as to render it difficult of detection. Possibly he met with only youthful specimens; for I find, on the contrary, that it is very dark, and so nearly opaque that the animal can scarcely be seen through it, at least in old individuals. The disk forms a simple circle. Though a beautiful creature, there is little in its economy sufficiently special to call for further remark.

The last species, *M. ptygura,* if I rightly identify it, is somewhat peculiar, and seems to approach in its form to the following genus. In October, 1849, I found two specimens of a fine wheel-animal which I could not satisfactorily identify with any

* I have given the history of this species in detail, with figures, in my "Evenings at the Microscope," pp. 302—310.

† In the "Intellectual Observer," for Feb. 1862, p. 49.

of Ehrenberg's descriptions, and which I therefore named, as a new species, *Megalotrocha velata*. I have, however, had reason since to think it was his *Ptygura melicerta* (see fig. *d*). The animal was not contained in any case, that I could discern, nor was it attached to any others of its kind; but the observations were insufficient to determine absolutely that these conditions were permanent. It laid a large egg in my possession, and actually under my eye, so that it was in adult age. On the other hand, it displayed two distinct eyes,—in general, a mark of youth in this family. Its general figure was somewhat trumpet-shaped, slightly swelling in the middle. The disk was very large, forming a continuous nearly circular outline, and partially surrounded by a layer of granular tissue. The foot terminated in an adhering sucker, whose figure resembled that of a glass stopper in a phial; the dilated extremity of this was capable of adhering to any foreign substance.

I come now to speak of the three species, which I propose to unite into the one genus, *Megalotrocha*. They have a disk remarkable (as the name signifies) for its great size; it forms a very broad circular or ovate figure, notched at one point. To be more precise, the course of the cilia is continuous all round, with the exception of the middle of the ventral side, where there is an abrupt indentation or sinuosity. But their most remarkable peculiarity is their social habit: they voluntarily seek the society of others of their own species at a certain age, before which they have been free and solitary, and then adhere together by the mutual contact of the bases of their feet, so that they project in a radiating manner on all sides from a common centre, thus constituting compound spheres, which sometimes swim at large on a roving commission, and in other cases are permanently anchored to some aquatic plant. I suspect in all cases (though Ehrenberg says it is not so in *M. albo-flavicans*) that there is secreted a common gelatinous envelope, corresponding to the isolated cases of the *Melicertæ*, but so agglutinated together by the proximity of the animals, and by the viscous nature of the substance, that a common ball of jelly is formed, pierced with cells in which the creatures dwell, each in its own.

My own personal acquaintance with this form is confined to *M.* (*Conochilus*) *volvox*, of which I found many clustered spheres, some years ago, in one of the tiny pools on Hampstead Heath (see fig. *e*). The appearance of these—from their form, their colour, and their association, and their majestic rolling movements—was very interesting.

The clusters are very distinctly visible to the naked eye, swimming slowly along, ascending or descending, by the motion of the powerful cilia that surround the head. Each cluster

consists of many individuals (I examined one of seventy) united by the extremity of the foot, and radiating from a common centre in every direction. The heads of all point outward, and the ciliary currents of all give the spherical clusters a slowly-revolving motion as they swim. An inexperienced observer might for a moment suppose that he had a group of large *Vorticellæ* before him, but the complexity of their organization soon shows the difference between them. This species displays the existence of muscles with remarkable distinctness, several of which run down longitudinally, and others go round the body transversely. The shape of each animalcule resembles that of a bell wine-glass when fully extended, of which the body is represented by the vessel and the foot by the stand; the latter, however, tapers to a blunt point, without any apparent division or expansion. The whole outline is constricted with transverse corrugations, and is capable, especially the foot, of forcible contraction in length. The frontal disk is large, and divided into two semicircular portions, round which the cilia seem to be set; yet, when they are in active rotation, the eye cannot discern any break in the ciliary crown. The centre of the front rises into a blunt cone, on one side of which projects a little jointed antenna, bearing a bristle at its tip. Ehrenberg describes four conical papillæ, all of which are sometimes bristle-tipped, but more commonly only the front pair. I, however, could detect but *one*.* The position of this organ, within the ciliary crown, is remarkable; its ordinary place being outside, that is, below its plane, as seen in *Melicerta*.

Two very minute eye-specks are seen, rather wide apart; and below is the gizzard-like mouth containing two hemispherical jaws, set with teeth. The viscera are pale yellow, and the jaws are orange-red; else the whole animal is colourless and very transparent. When a cluster is taken out of the phial in which it is swimming about, and put into the live-box, the number of animals lying over each other, if it be populous, is confusing. The numerous feet radiating from the centre like the spokes of a glassy wheel, and the multitude of crystal bells around the circumference—each surrounded by its crown of rapidly-rotating and strongly marked cilia, are almost distracting. Some display the front, some the side; some turn themselves so as to present to the eye a transverse view of the crown, others are almost vertical; it is only in the latter, when the eye looks down upon the disk, that the divided structure can be seen. Some are continually shrinking up by forcible contractions of the foot;

* From this discrepancy, and also from the silence of Ehrenberg respecting the very peculiar form of the egg (to be noticed presently), there is a possibility that mine may have been a distinct species from his.

and some are vomiting forth the flattened pale-yellow eggs which are ready in the ovary. This is, indeed, the first thing done as soon as a cluster is put into the live-box; the animals being probably excited by being caught and moved from vessel to vessel. Many eggs are presently seen, forcibly expelled from different individuals and whirling about in front of the animals. (See figs. *f*, *f*, *f*.) Ehrenberg says, that in *M. albo-flavicans* they are attached to the parent by a thread for some time; but in this case there is certainly no attachment: they are simply retained by the vortices of the ciliary currents. This was clearly shown in the case of one egg, which, on being ejected, for some cause or other, escaped being caught in the ciliary currents, and swam slowly away, with the original impulse, far out of the range of the parent. I did not trace the development of any of the eggs.

The form of the egg is very peculiar: it appears to be nearly circular, flattened on one side and convex on the other; there is considerable difference in their size; they are of a pale-yellow hue, marked with several blackish specks.

After having been some time, perhaps two or three hours, in the live-box, the animals begin, one by one, to separate themselves from the group, and to swim off in freedom. The foot, immediately after separation, shrinks up so as to be little more than a thick nipple, and sometimes shrinks completely within the body, within which it is seen much shortened and corrugated; the body is also enlarged and turgid at the bottom. The ciliary motion now carries it rapidly along, revolving on its longitudinal axis, until it is brought to the margin of the box or to the edge of the flattened drop of water, along which it then swims in a backward direction, the foot foremost; now and then it rapidly reverses its course, but invariably turns so as to keep the foot before. After pursuing this amusement a little while, it stops, becomes still; the action of the cilia grows feeble and languid: these organs hang over the side of the coronal circle like flexible hooks; the jaws cease to work, and the creature soon dissolves into a yellowish indistinct mass. I tried to feed them with indigo, sap-green, and carmine; but though the pigment, after being whirled around the ciliary currents, accumulated in masses outside the cone, I could not perceive that a particle entered the body of any.

The largest cluster that I examined, measured, when under the pressure of a compressor, about 1-30th of an inch in diameter, and the longest extended animal 1-50th. When the pressure was removed, these measurements were reduced respectively to 1-36th and 1-70th. An animal contracted in swimming independently was about 1-150th of an inch long.

Professor Huxley has given a valuable account of the struc-

ture and economy of *M.* (*Lacinularia*) *socialis*.* He finds the clusters of this species abundantly studding the leaves of *Ceratophyllum*, which grows in the Medway, near Farleigh Bridge. In general appearance and habits this species agrees with the one I have just described; the animals, however, are more slender, and the distinction between the body and the foot is less strongly marked. The eggs are of the ordinary form, not of the remarkable turban-like shape of those of *M. volvox*; they are laid in the cells of the gelatinous sphere, where they are hatched. Here the young live for a while; but as soon as the disk begins to assume a triangular outline, and the foot to be developed, they "begin to 'swarm,' uniting themselves by their caudal extremities, and are readily pressed out as united free-swimming colonies, resembling, in this state," the previous species. Ehrenberg says that seven or eight eggs are deposited in each cell; that these form a new cluster, swim away, and form an envelope of their own, but that, when only one is born, it attaches itself to the side of its parent. We may inquire how the young clusters of six or seven (and the young of one parent accumulated in the case at one time could never greatly exceed this number) increase to forty or more. Perhaps this last fact may help to guide our conjectures. Probably, as the individual young grow in size, the interspaces left between them, becoming wider, afford ample room for intruders; and the new progeny of these, as they are hatched, at once take their place, one by one, in the parent sphere, swelling its bulk up to the dimensions of maturity; and that the swarming does not begin to occur till these dimensions are attained. The free-swimming swarms are temporarily in the condition which in *M. volvox* is permanent, and may readily be supposed (as has, indeed, been done) to constitute a distinct species. As the Berlin Professor observes, "They have not yet the character of the genus [species], but are *Lacinulariæ* notwithstanding, as young frogs without feet, and with gills and tails, must still remain frogs."

Professor Huxley has discovered that another form of eggs, which he compares with the *ephippial* eggs of some of the water-fleas (*Daphnia*, &c.), is produced by *M. socialis*. They are inclosed in a double investing membrane, the inner of which sends off a partition that divides the contents into two equal portions. Cohn, however, believes that these are not proper eggs, but *gemmæ*, having analogy to the buds of a plant, while eggs are analogous to its seeds. New plants may be grown from either; but, physiologically, the plant produced from a bud or cutting is only a severed and independent part of the

* "Trans. Micr. Soc.," 1853.

individual life of the stock; but that produced from a seed is a new plant, a new generation.

Experience shows that this, like the former species, cannot long survive confinement. I have already mentioned the fate of *M. volvox* in my possession; Ehrenberg says of *socialis*: "In vessels of water they rarely support themselves eight days; they die and fall to the bottom, even if plants be growing in them."

EXPLANATION OF THE ILLUSTRATIONS.

Plate X. represents a shoot of *Nitella* with stationary *Melicertadæ* adhering to it, and a free cluster of *Megalotrocha*.

Fig. *a*. *Melicerta ringens*, viewed from behind.

b. The same, viewed from the side.

c. *Melicerta ceratophylli*, viewed from behind; with two eggs in its case, attached to the foot.

d. *Melicerta ptygura* (?) viewed from the side.

e. A large cluster of *Megalotrocha volvox*, freely rotating and swimming. Some are viewed vertically, some from the front, some from the side, and a few are closed.

f. Eggs of the same, held in the ciliary vortex, and seen in various positions.

The whole magnified about 350 diameters. All the figures taken from the life.

THE COMMON TRUFFLE (TUBER CIBARIUM).

BY JABEZ HOGG, F.L.S., M.R.C.S., ETC.

IT is, perhaps, not very generally known, that the curiously formed, irregular-looking mass, so much esteemed for its delicious taste, and sought after as a luxury, the truffle, is in truth a species of mushroom, more properly speaking, a subterranean puff-ball, or fungus.

The common truffle, *Tuber cibarium; Licoperdon Tuber* of Linnæus, and described by Pliny under the name of *Tubera sincera*, appears to have been well known to the ancients. The truffle of our markets occurs in rounded nodules, varying in size from a nut to that of a large potato, irregular in form, with a rough warty-looking black outer coat. It grows a few inches below the surface of the ground in several parts of England, Covent-garden Market receiving its supply from the downs of Wiltshire, Hampshire, and Kent, as well as France and Germany. Its existence, entirely removed from the action of light, is an anomaly even among plants of the fungus kind; for light, although not in a large degree necessary even to the fungus, is almost always indispensable to its full development. It would, therefore, be most difficult to discover, if it were not for a peculiar and penetrating odour, which dogs are taught to recognize; and by the aid of these useful animals its presence is detected hidden beneath the soil. Pigs are very fond of them; and in Italy advantage is taken of their instinctive knowledge of the spots, and natural propensity to dig them up, to gather a larger supply.

France produces three excellent varieties, the *truffe de Perigord*, with black flesh; the *truffe de Bourgogne*, with white flesh; and a third with violet flesh. The first is much esteemed, on account of its odour and tenderness, and from it is made a finer seasoning or flavouring ingredient for the luxuries of the table.

Riègel, with the desire of discovering the peculiar chemical principle which gives odour and flavour to the truffle, carefully analyzed the Perigord variety, and found it consisted of a brown fatty oil, with traces of a volatile oil, an acrid resin, osmazone, mushroom sugar, nitrogenous matter insoluble in alcohol,

prussic acid, phosphoric acid, potash, ammonia, albumen, pectine, and vegetable mucus, with fungic skeleton. So that the odour is chiefly due to a peculiar yellow empyreumatic oil, not unlike spirit of *hartshorn*. M. Vittadini, of Milan, was among the first to make a more careful examination of the truffle, both of its external and microscopical characteristics, and succeeded in throwing a considerable amount of light on its organization. His observations have been much extended by the researches of the Rev. M. J. Berkeley, Klotsch, Corda, and the Tulasne's. Vittadini pointed out that these fungi presented two essentially different types. In the one, *Hymenogastreæ*, the internal fleshy mass presents a number of winding cavities, lined by a membrane analogous to that which clothes the gills of the Agaric, and the superficial cells produce at their free extremities three or four spores, or seeds, which become detached, and eventually fill up the cavities.

The other type, *Elaphemycæ*, *Tuberaceæ*, comprising those of the truffle kind, and as may be surmised by the scientific name assigned to them—*Tuber cibarium*,—are plants characterized from the underground root presenting a fleshy mass, the outer surface of which constitutes the common envelope, or skin, termed the *peridium*, while the numerous narrow sinuous cavities are lined and in part filled up by filamentous tissue, mingled with cells of a peculiar form, and terminating in spores.

To place the truffle among the class *Tuberaceæ* would appear to be a mistake; for it can hardly be said that this curious underground esculent, a perfect plant destitute of leaves, stems, and roots, in any way resembles the genus *Tuberaceæ*, except in one unimportant particular, namely, external appearance. Every cell in the truffle is an assimilating surface; the whole plant is a reproductive organ; and every part of the structure performs the functions which, in the more complex plants of the *Tuberaceæ*, are performed by organs specially set apart.

The fungus genus, which claims the truffle, until very recently furnished us with but few varieties; the more careful researches of the Messrs. Tulasne made throughout France, enabled them to extend a before limited list to a hundred and forty-four species, comprehended in twenty-five genera of these plants.

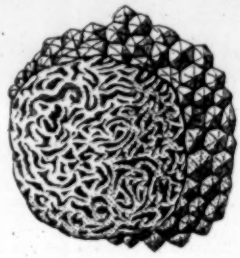
The whole family of fungi are developed from minute spores or seeds, which are continually carried about by currents of air. At length the seeds are deposited on a suitable soil: their growth is most rapid; when once rooted, they are extremely tenacious of life, and exhibit considerable powers of resisting frost, as well as heat; some seeds having been subjected to the boiling heat of water without losing their power of germination.

Truffles prefer a dry, light, calcareous soil, in woody grounds,

and are found growing throughout the whole of Europe, India, Africa, and New Zealand. "In some parts of France, as in Poitou," says Berkeley, "it is simply necessary, in order to their supply, to inclose a spot on the chalky downs, sowing it with acorns. As soon as the saplings attain a growth of a few years, the truffles appear, and a harvest is obtained for many years successively without further trouble." Thus it appears that the culture of truffles is reduced to as simple a process as that of most plants; but the apparent necessity of first planting acorns has given rise to much misapprehension on this head; for, in a French journal of science last year, a paper appeared, written with the avowed object of "*clearing up the mystery which has so long surrounded the reproduction and* ARTIFICIAL PROPAGATION *of the truffle*," which, the writer says, "is simply an underground species of *oak-apple*, produced by an insect on the rootlets instead of the leaves of the oak. The white oak is chiefly selected, and the young trees should be planted in a light porous soil,—a sandy or chalky soil is the best, so that the *flies may find ready access to the roots*. A southern aspect, with plenty of sun and air, is the preferable situation both for trees and flies. There are as many varieties of these special flies as of truffles. They are mostly of a small size, and make their appearance after rain has fallen, and during the warm months of July. In August and September they penetrate to the roots of the trees for the purpose of depositing their eggs. After the small puncture has been made by the fly, this portion of root separates from the parent tree, and goes on increasing in the same way as the oak-apple, and in process of time becomes food for the larvæ; which are hatched about March. Then commences the work of destruction, as the larvæ eat their way out of their winter prison, and pass through the usual metamorphoses to that of the perfect fly." The paper concludes as follows: "that by a careful application of the foregoing knowledge large plantations in the department of Vaucluse have been for a long period very profitable to their owner, A. W. Falon; and by digging up the roots with the chrysalides at the proper time, they have been transported in boxes to form other plantations equally profitable."

The microscope clears up all this ingeniously woven tale, and we read by its aid the life history of this remarkable underground plant; and although so extremely simple in its organization, we see in it the secret manner in which nature builds up her most complicated vegetable structures. A section from the fleshy-looking mass cut very thin, and viewed under a power of 250 diameters, is found to be chiefly composed of cellular substance, the interspaces of which are filled up by jointed filaments, homologous to the mycelium or spawn of other fungi,

1.



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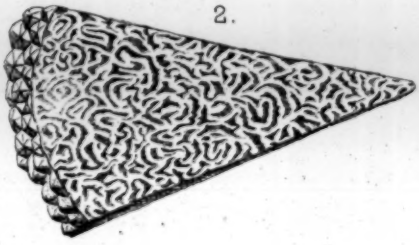

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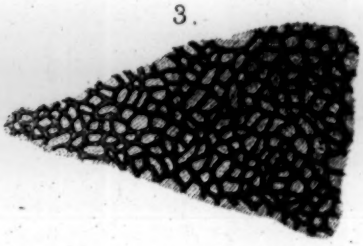

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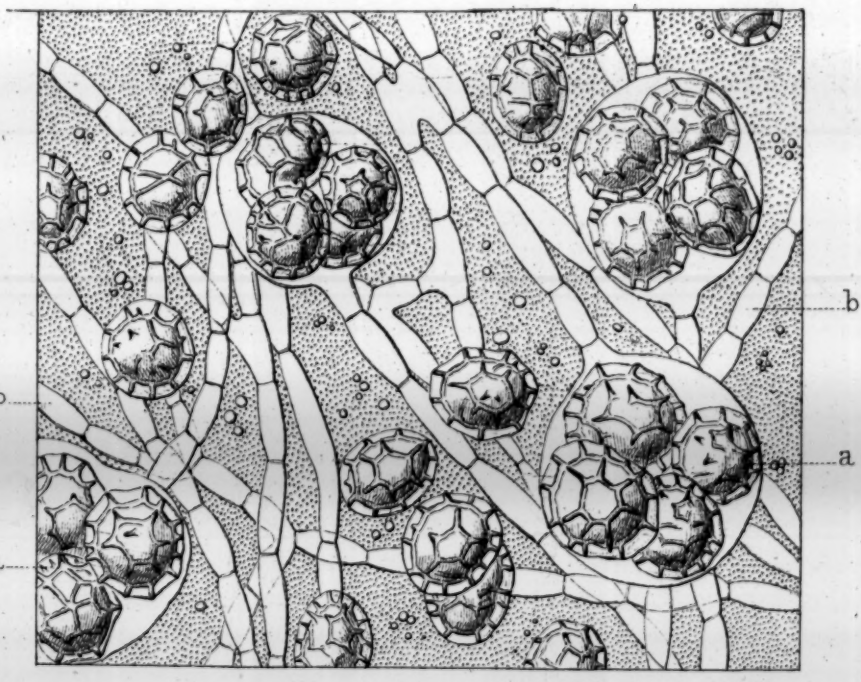

x 250.

Tuffen West, ac. W. West, imp.

The Truffle.

—in the mushroom, as an example, it is the mushroom spawn, —while the veins, the reproductive parts, contain in their cellular tissue minute oval capsules, with two or more globular yellowish seeds ; this curious structure having all the parts of nutrition and reproduction inclosed internally, instead of externally, as in other fungi. Plate XXVII., fig. 4, exhibits this last-named structural peculiarity; figure 3, the outer or cortical coat ; and figures 1 and 2, sections of small truffles, natural size.

In language somewhat more precise and scientific, we should say truffles are produced in this way ; the mycelium quickly decays and allows the fungoid body to grow on in an isolated condition. About September the ground becomes covered with numerous white cylindrical, articulated filaments, not visible singly to the unassisted eye, but by their immense numbers and rapid growth readily seen, and found traversing the soil in every direction. These white flaxen threads are continuous with other flocculent filaments of the same nature. In the young truffles the external layer is gradually consolidated, and in a short time the destruction of the flocculent filaments complete and lost in the young plant, which is soon isolated in the soil, and then the outer or cortical coat hardens, and ultimately has the appearance of a small nut. Thus, like other fungi, truffles are reproduced by spores, which give origin to filamentous mycelium and seed-vessels, the source of numerous offspring. Groups of spores are pretty objects; their stellate appearance reminds one of the Xanthidiæ; the mass of the full-grown plant at particular seasons is almost wholly made up of these bodies, the yellowish-brown coloured seeds. The observations of M. Vittadini had already indicated the curious arrangement of the black and white veins, which traverse the tissue of the truffle; and the more careful investigations of the Messrs. Tulasne have clearly shown their relations and destination.

The young truffle exhibits very irregular sinuous cavities, partly communicating with each other, and terminating sometimes at a single orifice corresponding to a depression on the outside. As they grow older, the partitions which separate the cavities become thickened, and the tissue comprising their surfaces is developed into a kind of longish soft hair,—tomentum, which obliterates them: hence result the two systems of veins; the one set coloured, corresponding to the partitions which separated the primitive cavities, the other white, forming the filamentous tissue, and filling up these cavities. The former are continuous with the external cortical layer or outer skin; while quite internally they are made up of a network of filaments or elongated cells (see fig. 4), running in the direction of the cavities; from this shorter filaments branch off, almost perpendicular to the first, and in the dilated extremities of these

are developed the seeds,—sporangia: the deep colour of the mass is owing to the brownish yellow of these seeds. The other set of white veins appear to be formed of the unproductive sterile filaments, originating like the former primitive partitions; but these veins or filaments being filled with air, present a dull white appearance when thin slices are examined by transmitted light.

In these plants, therefore, we have a double system of veins or laminated filaments; one set arising from the cortical tissue absorbing the surrounding moisture, and serving to transmit this to the cells in which the spores are formed, being therefore the organs of nutrition; the others white and opaque, terminating externally also, but conveying air to all parts of the body, and bringing the whole into contact with the sporigenous cells.

The spores are developed freely in the vesicular cells destined to produce them. They are limited in number in each vesicle; less than two is never seen in one vesicle; the hexagonal basket-work arrangement of each seed appears to close with a lid, and ten or twelve short spines project out from every point.

Beneath the external dark-coloured reticulated membrane is a second integument, smooth and transparent, easily separated by maceration, although it resists the action of chemical agents, and is not coloured by iodine. The simple cavity of the internal spore is filled with minute granular particles and oleaginous globules, suspended in a fluid probably albuminous, as well as the various chemical salts found by Riègel.

To proceed further with our microscopical investigation of the truffle will give no further insight into its minute structure, but it may be of interest to note a somewhat remarkable appearance during my examinations. Having cut the thinnest possible sections with a cataract-knife, moistened them with a single drop of distilled water, and subjected them to pressure under a Powell's compressorium, I watched with interest a series of currents round the circumference of the sections twofold in direction. I, as usual, attributed these to the capillary action exerted between the plates of glass. Putting them aside for an hour and again examining them, this time using a higher power and eye-piece, I noticed an intense action was still going on all round the edge of the glass cover, exactly resembling the ciliary action round the mantle of the oyster; at certain points losing the character of currents and presenting the appearance of myriads of atoms moving rapidly about, as in the phenomenon of "swarming" amongst the Desmids.

The sections were at the end of another hour removed from the compressorium, and kept moist by adding a drop of dilute

acetic acid; and in a few days they were once more subjected to an examination; when I found the *Anguillulæ aceti*, vinegar eels, developed in large numbers; and all the albuminous portions of the section eaten out or destroyed. It is just possible that the motion observed was produced by the presence of minute ciliated ova of the Anguillulæ;* and their subsequent development may have laid the foundation for the fly-theory formation of truffles.

* This is not very probable, for the author observed the ciliary action before applying the acetic acid. The eels are developed in vinegar *only*, without the addition of any decaying organic substance.—Ed.

DESCRIPTION OF PLATE XXVII.

Fig. 1. A small truffle (natural size) from which a slice has been cut to show its internal structure.

Fig. 2. A horizontal section of a large truffle (natural size).

Fig. 3. External cortical layer magnified 250 times.

Fig. 4. Internal structure. *a*, *a*, Sporangia; *b*, *b*, filamentous mycelium, magnified 250 times.

MISCELLANEA.

CHRONOMETERS AND ELECTRICAL CLOCKS.*

THE reason why the exertions of men of science are not always fully appreciated by the world at large is because the fruits of their labours do not in every case become immediately manifest. It often happens that a whole lifetime is spent in patient toil before the attainment of any considerable results, and even when these are published in the form of some new discovery, or the perfecting of some wonderful invention, the author is too often overlooked by the excitement-seeking crowd.

Thanks, however, to the advancing intelligence of the day, this is not likely to be the case much longer, and even now the worker in science is becoming better understood and appreciated, and is beginning to be highly respected by those who have no pretensions to more than every-day information.

Men are beginning to find that Science really has some direct and immediate connexion with their pockets and with their palates. Here, one misses a bargain because he has allowed the time-ball to drop before he was at his appointed post; there, another loses his train or his packet because he had neglected to set his watch by Greenwich time. And so men are reminded by their very business, and by their domestic habits, that whilst Science is willing to be impressed into their service for gain, she visits with absolute punishment those who neglect her advantages or underrate her importance.

When the trader finds that he has missed his bargain, his train, or his boat in consequence of the precision with which matters are conducted under the régime of Science, he ceases to despise Electricity and Astronomy, and may even go so far as to inquire into their practical application, and to promote it by contributing a mite from his well-filled purse to some useful or fashionable scientific association.

Such inquiries, too, lead him to discover the fact that more important issues are dependent upon the researches of men of science than his little bargains, his pleasures, or his disappointments. He finds that the fate of hundreds of human beings (including, perhaps, that of some dear friend or relative) may be sacrificed at sea in consequence of the want of scientific knowledge on the part of him to whose care their lives are entrusted. He hears that some careless mariner has failed to correct his timepiece, and that a sacrifice of life has been the consequence; but had he taken up the report which now lies before us, he would have known that "an error of two minutes

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* Report of the Astronomer to the Marine Committee, Mersey Docks and Harbour Board.

in a ship's chronometer" may cause a wreck with all its disastrous results; loss of life and property at sea, destitution and mournful misery on shore!

Surely, then, the man of science who provides the means of obviating such terrible evils as these is entitled to the gratitude and respect of his fellow men!

But the details of those patient and laborious investigations of which the world at large derives the practical benefit (often without knowing the source from whence it proceeds), are frequently clothed in such technical guise that a record of them would be unintelligible to a vast number of persons whose curiosity and interest would prompt them to seek such information; and this is another reason why the vigils of the worker often remain unknown and unrecorded, except for the benefit of a privileged few; and consequently his trials and difficulties do not meet with that reward which the world would be willing to bestow.

Now, although we do not mean to say that these observations apply in their entirety to the instance before us—for the labours of Mr. Hartnup, the able representative of Astronomical Science in Liverpool, are well understood and appreciated, and their practical results *force* themselves upon the notice of all who take the least interest in the subject—we may still adduce this as an example of what may be done by patient and arduous toil, without being fully recognized by the public at large; for we venture to affirm, that, many as are his friends and supporters who will have carefully perused his interesting pamphlet, they are far outnumbered by those who will have laid it aside without at all inquiring into its importance or the records of progress which it contains.

Possibly they may have been so unfortunate as to open it at pages 10 and 11, and, terrified by the long array of figures, they may have mistaken it for a table of logarithms, or something equally unintelligible to the mind commercial; but had they turned over another page they would have found that to Mr. Hartnup they owe the accuracy of their gold timepieces, and that his labours are intimately associated with all their mercantile concerns.

And now, what does this pamphlet really tell us? As the expositors of Science, standing between the abstruse and popular inquirer, we will endeavour, after our own fashion, to interpret its contents.

The Liverpool observatory is placed under the direction of John Hartnup, Esq., F.R.A.S., a well-known and highly esteemed astronomer and meteorologist, and perhaps his most important duty, one which cannot be too highly estimated, is the correction of ships' chronometers by the means of instruments and appliances placed at his disposal by the Mersey Dock Board. Upon the accuracy of a ship's chronometer may hang the lives of thousands, the issues of peace and war, the fate of individuals and of nations, for it is now employed not only to indicate the hour of the day, but also for a much more important purpose, for "if such clocks or watches could be made to show the correct Greenwich time at sea, then the mariner, on finding his local time by the position of the heavenly bodies, would know his longitude from Greenwich." We must presume that the reader understands the *rationale* of this statement, and he will perceive that an error of a few minutes in the captain's timepiece may take him out of his course, delay the delivery of his despatches, or lead his ship to destruction. For the purpose

then, of testing the accuracy of such instruments as are confided to his care, under every condition of climate in which they may have to be employed, Mr. Hartnup has an apartment suitably fitted up in his observatory, and ingeniously heated with gas, in such a manner as to secure for him, if requisite, a considerable variation of temperature; and in this room there are ranged, side by side, from 100 to 200 ships' chronometers undergoing the strictest comparative scrutiny.

The formidable list in the report to which reference has already been made, is simply a record of the variation of sixty-two chronometers which were compared and tested during five weeks in April and May, 1861, and also in November and December of the same year; and glancing our eye over the first column, we find that for the week ending November 9th, the mean daily rate of variation in the *least* accurate of these instruments was fifteen seconds, whilst the *most* accurate showed *no variation whatever;* and the average error in the whole sixty-two appears to be about $3\frac{1}{5}$ seconds per day.

This speaks well for the makers of these instruments, upon the accuracy of which, as already stated, so many interests are dependent.

The Astronomer of the Mersey Docks and Harbour Board does not, however, limit the employment of his energies to the attainment of precision in the working of marine chronometers for insuring the safety of life and property on the high seas, he also influences the movements of his townsmen through the time-balls and town-clocks which serve as their guide in daily life; and although perhaps not the most important, this will be to our readers the most interesting portion of his labours, and we shall communicate the results obtained by him in the words of his report:—

"All other observations taken with the Transit Instrument have been used for the determination of Greenwich mean time, which has been regularly communicated to the port by means of time-balls and clocks. The large clock in the Victoria Tower has six dials, each of which is eight feet in diameter. This clock has now been successfully controlled from the Observatory for upwards of two years, and the first blow of the hammer at each hour of the day indicates Greenwich mean time. On a calm day the striking of this clock may be heard at the Observatory, and we frequently compare it with the Normal clock. The time which sound takes to pass from the clock to the Observatory is two seconds and six-tenths, and so perfectly does the small clock at the Observatory control the large one at the Tower, that no sensible difference between the calculated and observed time can be detected. The striking is not, however, the most convenient test that we have of the accuracy of its performance. The large clock is made to send a galvanic current once every minute, and by so doing the needle of a delicate galvanometer is deflected at the Observatory, and the deflection of this needle is found to be simultaneous with the beat of the Normal clock. I am not aware that any clock so large as this was ever before made to perform with such marvellous accuracy. The mechanical arrangement for making this clock drop the time-ball has been found to answer well. For communicating Greenwich mean time to ships lying in the river or docks, a time-ball in so conspicuous a place as the top of the Victoria Tower is, I believe, the best means that could be adopted; but, for the convenience of those engaged in the manufacture and regulation of chronometers, and for the public in general, a clock

showing the hours, minutes, and seconds, from which the time may be taken at any instant throughout the day, appears to be the most highly appreciated. As a proof of this, on the 4th of February we caused to be counted the number of persons who appealed to the clock controlled from the Observatory, which is placed in the office window of the Magnetic Telegraph Company, and visible from the Exchange flags, and between the hours of six a.m. and five p.m. eighteen hundred and sixty persons took the time from this clock.

"It is scarcely possible to estimate the value of this extensive dissemination of accurate time, without referring to the various letters and memorials on this subject, addressed to the authorities of Liverpool, during the two or three years preceding the erection of the Observatory. They all dwell very largely on the importance of publishing, officially, accurate time for the benefit of mariners, chronometer-makers, and others; and it is stated in a memorial from the British Association for the Advancement of Science in 1837, that a captain could not at that time obtain the correct error and rate of his chronometer, as celebrated chronometer-makers had been found to differ from each other in the Greenwich mean time to the amount of two minutes. The memorial ends with the remark,—'these two minutes might cause a wreck.'"

By means of his "Rain-gauge," "Barometer," and "Anemometer," the downfall of rain, pressure of the atmosphere, and direction and force of the wind are daily recorded; and Mr. Hartnup is about introducing into the Observatory a new barometer, of which we hope one day to be able to give a description to our readers.

Concerning this instrument he reports as follows at the conclusion of his pamphlet:—

"The new self-registering barometer which is now being constructed, will make our meteorological observations much more complete. Some delay has been caused in the construction of this instrument by our requiring it to be different to those in general use. The record is usually obtained by photography, and as the tracing has to be developed, it is not available for some time after it is taken. For nautical purposes it is necessary that the changes in the pressure of the atmosphere should be seen immediately. We have therefore been obliged to adopt a different plan to that which is generally employed."

How completely interlinked the Arts and Sciences are becoming; and how mutually dependent one upon another, when the record of the state of the atmosphere must be made by photography! How rapid the increase of knowledge, and of man's wants, when even that process is not sufficiently subtle for his purposes!

PROVINCIAL INSTITUTIONS AND SOCIETIES.

The amount of space occupied by our Exhibition notes and deferred articles precludes us from giving to this section of our periodical the attention which it merits, and we shall therefore postpone the consideration of the progress of Field Clubs, Science Schools, and Philosophical Societies until our next issue.

REVIEWS.

The Student's Manual of Geology. By Professor J. B. JUKES, M.A., F.R.S. Black.

WHEN one remembers that in a subject so well understood as arithmetic, it is only within the last few years that a good student's text-book has been written, it is perhaps too much to expect perfection in any manual of geology. Nor is it to be found in this one, which is sometimes dwarfed in plan, and occasionally erroneous in theory and fact. It is, however, by far the best book in our language for the real student: philosophically conceived, it treats in dependent succession, and at length somewhat commensurate with their relative importance, of all the subordinate parts of geology. It has been too much the custom to give in manuals only some of the last results of science in the history of the earth's crust; here, however, the student is introduced to the machinery by which these conclusions are won, and by mastering which he may work out more. The first part, admirably treated, and forming half the book, deals with rocks from a physical point of view; the second part is palæontology and limited to fifty pages; so that the third part, which is the history of stratified rocks, worked out by means of geognosy and palæontology, does not follow naturally. This subject of old life might have been treated typically, without trespassing on Owen's "Palæontology," so as to give the student better help than the chapters on laws of life, which are in many cases only guesses never yet challenged; the third part is excellently illustrated with figures of 320 of the more characteristic fossil species, and numerous sections and diagrams, of which the book contains 125. In this portion the author's careless treatment of the biological part is occasionally evident in the way in which genera still living are marked as extinct. These, however, are slight defects, and of no moment for the student, who will treasure the book, and find himself enticed onwards by the luminous writing.

RECENT WORKS ON ASTRONOMY.

The Orbs of Heaven. New Edition. *Popular Astronomy.* New Edition. By O. M. MITCHELL, LL.D. Routledge.

PERHAPS, as Professor Mitchell is an American, and as his country has of late been associated in our minds chiefly with strife and bloodshed, there may be many amongst our readers who have neither heard of him, nor yet had the privilege of reading his works.

If so, we recommend them to read "The Orbs of Heaven;" and then we think that we may safely leave them the option of perusing his "Popular Astronomy."

"The Orbs of Heaven" left an impression upon our mind somewhat resembling that which we experienced on reading Moore's "Epicurean," so rich is it in imagery and poetry; and, certainly, we have never met with a work so well adapted for encouraging a taste for science. The poetical conceptions of the author, or rather we should say, the poetical embodiment of scientific facts, which come upon the reader by surprise in various parts of the work, cause it to read more like a fairy tale than a record of scientific discoveries; and we never recollect having read anything by which we were so much enchanted as by his description of the lonely astronomer, who, from his "rocky home," witnessed the eclipse which he had predicted; and whose soul was stirred to praise his Creator, the great God whose hand guided the spheres in their path, whilst, in the valley below, stricken millions fell to the ground in despair, or sought by the clangour of brazen trumpets to conciliate their offended deities!

Again, in treating of the stability of our solar system, he shows how certain slow changes are taking place in the orbits of the planets; how these are expanding or contracting, and rocking up and down; that all these changes, however, have their limits; and when, he says, these variations shall, after a series of ages, have attained their maximum, and before a new cycle of movements shall be inaugurated, "*the great Bell of Eternity will then have tolled* ONE."

We recommend every parent who desires to inculcate in the minds of his children a love of science and admiration of the grander aspects of nature to place in their hands this attractive volume; and lest some youth might be tempted from its perusal to take up Professor Mitchell's other work, "Popular Astronomy," and should do that of which few youths are guilty, viz., read its preface, we recommend the publishers to omit this elegant and remarkably grammatical appendage from their next edition. We find it difficult to believe that it has been composed by the author of "The Orbs of Heaven."

As a handbook, "Popular Astronomy" does justice to its title. It is easy enough for young beginners, diversified here and there with sketches of the past history of science, and illustrated with tolerably good woodcuts. Of a totally different character is the little brochure, entitled

The Hand-book of Astronomy. By G. F. CHAMBERS, F.R.A.S. Murray.

IF the reader simply desires amusement, he had better not open the pages of this book. If he wishes to form a fair conception of the appearance of the heavenly bodies through the telescope, then let him glance at the beautiful plates with which it is illustrated; and should he desire to become a student of astronomy, we venture to say that such a cursory glance will tempt him to dive into its contents; but he must be prepared for *work*—for earnest work—such as Mr. Chambers has done in compiling this excellent text-book.

The author has availed himself of every legitimate source of information,* in addition to his own experience, and has spared no pains to bring his treatise up to the latest date.

As our readers will have observed from these few remarks, we do not regard this as a popular work on astronomy in the general acceptation of the term; it is one that is likely to find favour in schools of every description, more especially do we recommend it to teachers in science classes.

The Common Sights of the Heavens, and how to see and know them. By Capt. Drayson. Chapman & Hall.

A LITTLE work which professes to give "a simple description of the various sights which can be viewed in the heavens during the day and night." This task is accomplished in a very creditable manner. The writer treats successively of the Sun, the Moon, Venus, Jupiter, Mars, Saturn, the rest of the planets, the fixed stars, comets, and meteors. He describes graphically the appearances presented to the naked eye, and those which are brought within our reach by the telescope. In explaining the changes and motions which distinguish each of the heavenly bodies, he uses language which is singularly clear and simple. He imparts an additional charm to the subject by comparing the probable climatic or other conditions of the various planets, &c., as indicated by the obliquity of their axes, and the period of their rotation with the similar conditions now existing on our own earth. Thus he shows that great extremes of heat and cold obtain successively over the larger portion of the surface of Venus; whilst Jupiter has an exceedingly equable climate. By means of diagrams many important astronomical truths are elucidated. The illustrations consist of carefully-drawn chromo-lithographs; the heavenly bodies being represented on a blue ground, a system which has of late found considerable favour, being employed in both the works already noticed, and very successfully in Keith Johnson's "Atlas of Astronomy."†

With regard to the work under consideration, we may remark further, that it describes easy modes of discovering the position of the chief planets and fixed stars for many years to come. In short, it is a work admirably adapted for exciting the interest of the young in some of the many wonders which are the province of astronomy, and for explaining its chief laws in a lucid and agreeable manner.

It is, however, very much to be regretted that the author has given free license to his speculations. The book abounds in theories with regard to the origin of the worlds and their present condition, very many of which are merely fanciful, whilst not a few are unfortunately at variance with the present state of scientific knowledge. Thus he thinks the sun may

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* Amongst other authorities Mr. Chambers draws very judiciously upon Galbraith and Haughton's "Manual of Astronomy," recently published by Messrs. Longman, one of a well-known and serviceable series, edited by the two learned Professors at Dublin University.

† Edited by Hind. Blackwood.

be as cool as the earth, that its particles may be charged with a "subtle force somewhat similar to electricity," which produces heat and light only when entering an atmosphere; and that the rotation of the sun may "in some way" cause the rotation of the various planets; that the volcanic condition of the moon is caused by its long-continued exposure to the sun's heat, a rather extraordinary assumption; that the moon may attract the waters of the ocean or the atmosphere, and, then, by the "subtle chemistry of nature," form one for herself, from the materials thus procured; that a dense atmosphere might cause the smouldering volcanoes of the moon to "burst out into fierce flames;" that comets may be "the agents for gathering up all those gases or used vapours which may be thrown off by the sun and planets," and so on. The writer, again, confounds magnetism and electricity, and thinks the Aurora may be caused by the escape of a superabundance of magnetism in the earth, and by the rapid passage through the atmosphere of the "magnetic element," a state of things not recognized by the science of the present day. It is attempted to be shown that the present condition of some of the planets may be similar to that of the earth in former geological periods. Thus he supposes Venus to be at present passing through a glacial epoch, although on the earth we find glaciers (and, therefore, icebergs) only in connection with perpetual snow—and the conditions in Venus are against the probability of snow being there perpetual. We may remark, in passing, that the mammoth is described, perhaps to give a popular idea of it, as a "gigantic bull;" we think it would have been equally popular, and at the same time more strictly scientific, to call it an elephant.

We might allude to other instances of inaccuracy besides those already quoted, but enough has been said to show how necessary it is for scientific writers to be guarded in speaking of those branches with which they are imperfectly acquainted, and no man can be acquainted with every branch of knowledge. But it is far more difficult to eradicate an error than to inculcate a truth; and it is of special importance in books intended for the young, that nothing should appear in them which is inconsistent with sound science. With these exceptions we can heartily commend Captain Drayson's interesting little volume to our youthful readers.

The last but by no means the least interesting astronomical treatise which we have to bring under the notice of our readers is—

A Survey of the Astronomy of the Ancients. By Sir G. C. Lewis, Bart. Parker, Son, & Co.

THIS book, as its title indicates, is of a totally different character to the preceding ones, dealing only with the ancient theories of the universe; and there is one word broadly stamped upon its pages; namely, "care." No statement is advanced, no theory confirmed or contradicted, before every authority has been carefully considered, and an unprejudiced judgment arrived at; and we have seldom seen a treatise which bears the marks of such patient research as the one before us.

Neither need the author regret the pains which he has taken to prepare the "survey" with the utmost accuracy, for he has rendered it a most valuable work of reference for students, in whose minds it will clear up many doubts.

For example, if a tyro were to take up two of the works already referred to, which do not pretend to treat of ancient astronomy, he would find in both of them that the Pythagorean and Copernican systems of the universe are regarded as identical, or nearly so, each having the sun for its centre. The uninitiated student would be puzzled to find these two systems confounded, for it is generally understood that there was a great difference between the theories of the two astronomers who were 2,000 years removed from each other.

A reference to Sir George Lewis's book will, however, explain the difference between the two theories:—

The Pythagoreans believed that the earth and the heavenly bodies, *including the sun*, revolved around a "central fire," a body of which they had but a vague conception; whilst Copernicus placed the sun in the centre, and thus propounded the true solar theory. Pythagoras and his school may be compared to the man who, after a life-long effort, catches a glimpse of some new theory, or constructs the model of some valuable machine, which is rendered useless by its imperfection; whilst Copernicus resembles some gifted successor, who, having had the benefit of his ancestor's experience, coupled with that of intervening ages, sets his mind to work, and completely solves the problem, propounded and in part unfolded by his predecessor.

Of Sir George Lewis's book we are compelled also to say that it can hardly be termed "popular;" but it will be found interesting to all students of the science, and will be largely employed in educational establishments.

The second portion of the volume is devoted to chronology, and has given rise to a controversy on "Egyptology;" on the construction of the records left by the Egyptians concerning the history of our race. It has nothing to do with the subject of astronomy, however interesting it may be, and ought to have been more clearly separated from the first portion of the work; for as it stands at present the reader is led to expect a return to the original subject, an expectation in which he is doomed to disappointment. We have said enough to show how highly we value this instructive work, and recommend it to the perusal of all who are interested in the history of astronomy in past ages.

SCIENTIFIC SUMMARY.

QUARTERLY RETROSPECT.

ASTRONOMY.

The Missing Nebula.—"The lost Pleiad" has at length reappeared (although with greatly diminished lustre), but it has hitherto been only visible in the gigantic Pulkowa refractor. Having received information of its disappearance in December, 1861, M. Otto Struve lost no time in turning his great telescope to that part of the heavens, and on the first favourable night (December 29, 1861), after the usual few preliminary adjustments of the eye (in adapting it to the detection of faint objects), he had the pleasure of distinctly recognizing "some traces of nebulosity to the south of a star of the eleventh magnitude." M. Winnecke confirmed the observation,—assigning to the nebulosity the same position as M. Struve. Three months of unfavourable weather at St. Petersburg followed this bright night; and it was not until the evening of March 22 that any further opportunity occurred of inspecting the object. On this latter occasion, however, the correctness of the previous observation was fully established. The nebula appeared considerably brighter than in December, so much so as even to allow a slight illumination of the field of view. The sketch given by M. Struve fully agrees with that observed by the writer of this notice in 1855, showing a small elliptical nebula of two minutes in length, much brighter at one extremity than the other. The celebrated observer who detected the reappearance of the nebula, is of opinion that it is variable in lustre,—that its light had considerably increased between December and March, although he thinks that the extraordinary transparency of the atmosphere in the latter month may have added to the contrast. As an example of contradictory evidence, and of the little reliance to be placed on negative evidence, it may be stated that M. Julius Schmidt (of the Athens Observatory) was looking for the nebula on the nights of March 19, 20, 21, 24, and 25, in a perfectly clear sky, but not the least trace could be perceived of it. On March 26 and 27 the same result happened, although the glasses of the refractor were cleaned in the meantime, and precautions were taken to hide the light of some small stars in the field. The sharpness of M. J. Schmidt's vision and his conscientious accuracy are so well known, that this is not of the least detriment to his talents. It is of the statements of those observers who see everything, with the smallest telescopes and under the most adverse circumstances, that we are suspicious. M. Schmidt had a smaller telescope than M. Struve—had he had the assistance of a sixteen-inch object-glass we have no doubt but that he would have succeeded equally well. M. Schmidt adds

something to the history of this object ;—he looked for it in 1860 and 1861, but it was "nowhere." The last observation of D'Arrest is Jan. 12, 1856, although the writer of this notice is of opinion that it was seen by him in the latter end of that year.

Companion of Sirius.—The existence of a companion of this, the brightest star of the Northern heavens, is now beyond doubt. As previously noticed, it was discovered by Alvan Clark, with his new equatorial of 18½ inches aperture, at the beginning of the year, and his observation was speedily confirmed by Professor Bond, of Cambridge (U.S.), on February 10 ; at Paris on March 20, and, finally, by M. Lassell at Malta, on April 11. But although thus distinctly verified, the micrometrical measurements, as M. Lassell notices, greatly differ. For instance, on February 10, the distance was measured at 10 seconds and 37 hundredths ; on March 20,* at 7 seconds and 4 tenths ; on April 11, at 4 seconds and 92 hundredths. M. Lassell however adds, "I cannot accept the conclusion that there can have been a real motion in the star sufficient to reconcile these measures." The difficulty of micrometrical measurements with a flashing star like Sirius will be readily comprehended by all astronomers. It remains to be seen whether the companion is physically or only optically connected with the large star—in the last case similar in type to Beta Orionis and Antares.

Mountains on the Moon.—Mr. Birt announces the rediscovery of the missing lunar crater *Alhazen*, situated on the western border of that conspicuous object—the *Mare Crisium*. It was first noticed by Schroeter, who employed it for measuring the libration, after which some confusion appears to have arisen, and it was even supposed to have disappeared altogether. The Rev. Mr. Webb has given the full history of its changes as observed by Schroeter, who considered that its appearance was too variable to be accounted for by the varying angle of illumination. At first Schroeter observed it as a dark grey spot ; at other times he perceived it as a very deep crater, with a small shadow. Mr. Birt, upon attentively considering this object, has reason to think "that it consists of two nearly parallel ranges of mountains—the Eastern range forming a part of the actual border." He appears to think that the appearance of a crater is produced by the varying shadows on the surface of the moon by those two mountain-ranges. It is satisfactory to know that the observations of different observers between 1823 and 1829 have been confirmed.

An important work on the topography of the moon has just been announced, which calls into requisition the valuable aid of photography to give a "local habitation and a name" to the various features of the lunar surface. It is entitled "Our Satellite, a Selenography according to the present State of Science, by Dr. A. Le Vengeur D'Orsan." It is inscribed by permission to Lord Brougham, and receives the high commendation of the Astronomer Royal. The first photographers of the day are said to have borne testimony to the value of the illustrations, which include numerous woodcuts

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* There appears to be some error here. On referring to M. Chacornac's measures, we find that the distance on March 20 was 10·4″, and on March 25, 10·43″, agreeing very closely with Mr. Bond's measures on February 10. M. Lassell derives his information from *Galignani*.

and lithographs, where accuracy of detail has been principally kept in view. We trust that "Our Satellite" may be liberally patronized and find a place both in the libraries of the learned and the drawing-rooms of the rich, where the beauty of the photographs will no doubt be fully appreciated.* The publisher is A. W. Bennett, 5, Bishopsgate Street Without, and the first number is to appear on July 1.

New Comets and Planets.—We have not to record any discoveries in those objects during the last quarter. It may astonish many, however, to learn that the great comet of July, 1861, is still visible. It was observed, between March 20 and April 16, at St. Petersburg. On July 1 it comes within a degree of the North Pole, at about four hours of right ascension; but, it is needless to add, that it can only be perceived by the help of the most powerful telescopes. M. Struve thinks that the light of the comet is variable, and does not depend on the distance from the sun and earth altogether. On April 16 it showed distinct traces of concentration. The orbit, calculated by M. Seeling, and which gives a period of 419½ years to this comet, appears from those later observations to be the most correct. In regard to planets, it may be stated that between May 29 and June 13 of 1861, an object was observed for Maja, at the Hamilton College Observatory (U.S.), which turns out, however, to be a different object. It has received the name of *Feronia*, and is No. 71 of the group of asteroids. It may be expected to reappear in the month of September, when, no doubt, it will be eagerly sought after. The comet of Encke was observed by Mr. Hartnup at the Liverpool Observatory up to January 25 of the present year. On March 22 the comet of July, 1861, was estimated of the same brightness as the "missing" nebula by M. Struve.

Solar Spots, &c.—A circular spot seen upon the sun's disk, in 1862, March 20, between 8h. 37m. and 8h. 59m. A.M., is worthy of notice from the extraordinary motion which was perceptible. It was observed at Manchester by W. Lummis, Esq., whose observation was confirmed by a friend. During the above interval it appeared to move over about twelve minutes of arc; although, from the diagram communicated, Mr. Hind thinks it could not have been more than six minutes. The spot, according to Mr. Lummis, was quite circular, perfectly defined, and about seven seconds in diameter. The sun was particularly free from spots for several mornings previously.

Planets.—Mars will be a very conspicuous object during the autumn months, arriving at opposition at the beginning of October, when his apparent diameter will amount to 22 seconds. As this planet is above the equator at this epoch, it will be much more favourably seen than during the opposition of 1860, when, although its diameter amounted to 22·6 seconds, it was at the same time 28 degrees of south declination, which, of course, made any delicate observation almost impossible in those latitudes. Many years must elapse before the planet will be seen again to such advantage.

Variable Stars and their Measurement.—The subject of variable stars is one

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* We have seen two or three proofs of these photographs, each of which represents different portions of the moon's surface, and consider them very well executed.

of great interest to the amateur astronomer, who, by constant practice, can bring his eye to detect very small fluctuations of brightness. As an example of the exactness with which their periods are determined, we might cite the case of the star S Cancri, the minimum of which was observed by M. Schmidt, at Athens, on April 16, 9h. 27·5m., or within one-third of an hour of the time foretold by Professor Argelander. Mr. Searle, of Cambridge (U.S.), proposes a very simple photometer, consisting of a plate of glass the faces of which are inclined to each other by a few minutes of arc. By covering the object-glass of a telescope with this, the image of a brighter star can be reduced to that of a fainter one seen with the full aperture, and comparing the areas of the covered and uncovered parts of the object-glass, the real light of the two stars may be arrived at, taking into account the absorption and reflection of the plate. It is doubtful, however, whether the older and simpler plan be not more commodious and gives equally good results.

Variable Nebulæ.—M. Schmidt points out that a small nebula, whose place for 1855 is 11h. 16·5m. of R.A. and 90° 22′ of N.P.D. (inserted in the Bonn Star Maps), and which should be visible with a two-foot telescope or comet-seeker, has become so faint that it is seen with the greatest difficulty with the large refractor of the Athens Observatory. There can be no doubt of its former lustre and its present faintness. As this object is now visible in the heavens, perhaps such observers as possess good telescopes may turn their attention to this interesting object. Sir J. Herschel, in a letter to Mr. Hind, furnishes another example of a missing nebula. This one was twice observed by Sir W. Herschel, who, in 1784 and 1787, saw two nebulæ close together, the places of which were respectively 12h. 22m. 14s. and 12h. 22m. 29s., with N.P.D. 75° 33′ and 75° 36′, only one of which is now visible, although they are noted as being of nearly the same brightness. A telescope of four inches aperture should show both objects.

Nebula of Orion.—M. Lassell has discovered a new star in the trapezium of Orion, situated near Theta, which appears to be a full magnitude less than that known as the sixth star. With his giant reflector, and under the transparent sky of Malta, he has obtained some excellent views of this wonderful object, and intimates his intention of making it the subject of a fresh investigation. M. Struve has come to the conclusion, from numerous and careful observations, that the central regions of this nebula are subject to rapid changes of light, and is about to publish an extensive memoir on the subject.

Saturn.—Between May 17 and August 12 the ring of Saturn is invisible. A fine opportunity is thus afforded of observing his satellites. These latter, with their eclipses and occultations, have been seen to great advantage during the present spring. M. Lassell, on one occasion, saw them all in the field at the same time, with the exception of *Japetus*. This distinguished observer is of opinion that if Uranus has more than four satellites, those which are undiscovered are very much fainter than those which are visible in his telescope.

Miscellaneous.—Professor Littrow has discovered in the *Vienna Times* of April 27, 1820, a notice probably bearing on the intra-Mercurial Planet. A round, well-designed circular spot was seen by Mr. Steinheibel on February 12, 1820, at 10.45 a.m., distinguished by its "equally circular atmosphere

by its orange-red colour, and especially by its unusual motion, completing the diameter of the sun in nearly five hours." Mr. Steinheibel was no novice at solar observations, having pursued those phenomena for many years. The missing nebula above pointed out by Sir John Herschel has been found by M. Chacornac (on April 19). It may, however, have been invisible when looked for by M. D'Arrest. Mr. Dawes has frequently observed the shadow of Titan on Saturn's disc. That satellite will pass over the planet on July 4, 7.30 p.m.; July 20, 6.47 p.m.; and August 5, 6.3 p.m. (these are the approximate times of ingress). He thinks it may be seen by a five-foot telescope of four inches aperture.

BOTANY.

NEW Upas Tree.—Dr. Berthold Seeman describes a sixth species of Upas, met with in Fiji, which is not, however, absolutely new, though now accurately described for the first time. It appears to have been originally discovered by Dr. George Bennett, of Sydney, after whom it is now named *Antiaris Bennettii*. Though poisonous, its properties are not such as are ascribed to the deadly Upas of Java, and it is remarkable that it always appears in a cultivated state, no truly wild plants having been found either by Bennett or Seeman. It is usually found planted in the neighbourhood of temples, and from the surpassing beauty of its foliage and fruit, it is suggested as a probable future inmate of European conservatories.

New Species of Clerodendron.—The advantages derived from the use of Ward's cases in transmitting plants from tropical countries are well illustrated by the success with which the above plant, Clerodendron Thomsonæ, has been cultivated in the Edinburgh Botanic Garden. It is a verbenaceous, shrubby, twining plant from Old Calabar, whose showy flowers, having a white calyx and crimson corolla, and growing in numerous clusters, render it a desirable addition to conservatories. It is described, with a plate by Professor Balfour, in the *Edinburgh New Philosophical Journal* for April.

Nardoo Plant.—The fate of the Burke and Wills exploring party in Australia, which started at the end of December, 1860, with the intention of crossing to the Gulph of Carpentaria, has caused so much interest and sympathy, that the above plant has excited considerable attention from its association therewith. When nearly exhausted, the party sought the assistance of the native blacks, who gave them some "pounded Nardoo seed." The Nardoo plant was afterwards discovered by them, but the collecting and pounding of the seed was too much for their reduced strength. Although, however, the blacks live so much upon Nardoo seed, it does not appear to have been sufficient sustenance for European constitutions, for notwithstanding a plentiful supply, Wills expired. Some of the seeds found by his side have reached this country, and an attempt to cultivate them will be made at the Edinburgh Botanic Garden. The Nardoo appears to be a species of *Marsilea*, or Pepperwort, probably *Marsilea quadrifolia*, a cryptogamic plant, allied to the Lycopodiaceæ.

Vegetable Types.—The predominance of these types in Eastern America and Eastern Asia, as compared with the few restricted to Europe and Africa,

combined with other circumstances, Professor Oliver thinks, favours the idea that a migration of forms has taken place north of the Pacific, by an overland communication, which may have existed during the tertiary epoch, somewhere about Behring's Straits, or the line with the Aleutian islands; and to this cause is probably due the community of types in the Eastern states of North America and the Miocene of Europe.

Distribution of Fungi.—The eminent mycologist M. Fries remarks that the lowest forms, as Penicillium, may be found alike on the Alps of Lapland and in the Libyan desert; while, for the higher forms, heat and humidity are peculiarly necessary. Hence the Hymenomycetes and Gasteromycetes only appear when the weather is peculiarly favourable, or after abundant rains. Heat, however, is more essential for plants of higher organization than for ungi, inasmuch as many higher species of Agaric flourish at the close of autumn. M. Fries recognizes the existence of two zones peculiar in their fungaceous growth—a temperate and a tropical zone. In the temperate zone, the Fungi are distributed in a very uniform manner; while in the tropical regions there appears to be a more special plan of diffusion in the several countries. The whole of the rather long paper of this illustrious and lamented mycologist is well worthy of perusal, and of the highest interest. It will be found in the "Annals of Natural History" for April, having been translated from the "Annales des Sciences Naturelles." It originally appeared in the "Transactions of the Academy of Upsala."

Potato Disease.—M. Fries observes that this disease is accompanied by the growth of several species of Mucedo; but their presence, nevertheless, is evidently nothing more than the *consequence*, and not the efficient cause of the morbid affection.

New British Mosses.—Mr. W. Wilson, of Warrington, announces *Bartramia cæspitosa* (Schimper), a Swedish species, in a new marshy spot near that place. *Hypnum Eugyrium* (Schimper) has been found by Dr. Wood, of Manchester, near the Rumbling Bridge, Fifeshire. There are only one or two other British stations known. Several other mosses have been recently added.

Vegetation of the Island of St. Paul.—The Austrian exploring expedition in the "Novara" having investigated the botany of this remarkable island, the results may be summed up in 56 species of plants, independent of moss, besides a few introduced, cultivated species. The former consist of 11 aboriginal flowering plants (of which 6 are grasses and 1 a rush), 2 ferns, 1 lycopodium, 3 mosses, 2 liverworts, 4 lichens, and 33 algæ. The only mould on this island is formed by the decay of the plants, chiefly the grasses, yet it is in some places several feet thick.

The Cotton Plant.—The cultivation of cotton in other countries than the Southern states of America is a subject of much interest. On the banks of the river L'Habras, in Algeria, is a vast plain, containing about 650,000 acres, on most of which cotton would grow. Extensive works for irrigating this district are in the course of construction, and several companies (one of them English), as well as private individuals, are already making a start in this promising field. The climate is healthy, excepting that during August and September ague prevails, which may, however, be in in a great measure avoided with due care; and labour is very cheap.

Several distinguished botanists have recently been called from the scene of their labours. Carl Ludwig von Blume, M.D., of Leyden, died at that city in February; and another eminent Dutch botanist, Willem Hendrick de Vriese, expired at the same place on January 23rd. In our own country, we have to lament the death of Mr. Wm. Borrer, F.R.S., a name indissolubly connected with the subject of Lichenology.

CHEMISTRY.

PURE CHEMISTRY.—Our last quarterly retrospect of Pure Chemistry was introduced by a few facts which had been lately discovered respecting the divisibility of matter. More recent researches have shown that even the incredible numbers obtained in the former experiments fall far short of what we now know must be the actual fact,—in the case, at all events, of some volatile liquids. In the course of some experiments on the absorption of heat by gaseous matter, Tyndall has proved that air, which in its pure state is perfectly transparent to radiant heat, becomes absolutely opaque to that force if it contain a minute trace of some compound gases and vapours. A layer of ammonia three feet long is perfectly black to heat emanating from an obscure source. At a tension of one inch of mercury, the absorption of sulphurous acid is 8,000 times that of air; and the perfectly transparent vapour of boracic ether, at a tension of the tenth of an inch of mercury, has an absorbing power upon heat 186,000 times that of air. It is with this latter body that some most astonishing results have been obtained with respect to the divisibility of matter. By admitting a minute trace of boracic-ether vapour into the experimental tube, exhausting it to the tenth of an inch of pressure by means of air-pump, then admitting pure air into the tube and re-exhausting it to the same tension, the absorptive properties of the vapour could be experimentally observed when only the most infinitesimal fractions of an atmosphere were present. By repeated exhaustions and sweeping out of the tube by pure air, the professor found that the action upon radiant heat of an amount of boracic ether vapour, possessing a tension of only the one thousand and twelve million five hundred thousandth (1-1,012,500,000th) of an atmosphere was easily measurable. The actual weight of boracic-ether vapour present in a cubic inch of air at that tension is so infinitely small as utterly to defy the attempts of the human mind to comprehend it.

Cæsium and Rubidium.—M. Grandeau, whose researches on the two new metals discovered by spectrum analysis, Cæsium and Rubidium, were briefly noticed in our last number, has continued his investigations, and now finds that the latter metal is one of the most widely-distributed bodies in nature, being always present in the mineral constituents of beetroot, tobacco, coffee, tea, grapes, and other vegetable substances. These bodies of course derive it from the soil, and M. Grandeau gives data by which it is shown that the amount annually absorbed from an acre of land by a crop of beetroot is somewhat considerable, and by no means to be neglected by agricultural chemists in their experimental inquiries into the inorganic food of plants.

Eli Blake, jun., of New Haven, thus explains the discovery of these

new and rare metals in Triphyline:—"Having obtained a quantity of the residues of the preparation of lithia from triphyline, which gave, when examined in the spectrum apparatus, evidences of the presence of rubidium and cæsium, I have, at the request of Professor Bunsen, made an analysis of it. After the removal of the iron and phosphoric acid, and the conversion of the sulphates of the alkalies into chlorides, it was found to contain:—

Chloride of lithium	... ...	40·98
,, potassium	... ...	9·29
,, sodium	... ...	50·04
,, cæsium	... ...	0·11
,, rubidium	... ...	0·18
		100·60

"The method of estimating the rubidium and cæsium depends upon the insolubility of the platina chlorides as compared to that of the same salt of potassium; and the difference of solubility is not so great as to give very accurate analytical results. The above approximation, however, serves to show that, like some other minerals containing lithia, triphyline contains small quantities of these new and highly-interesting alkaline bases."

Fizeau has recorded a curious and somewhat paradoxical experiment on the light evolved by burning *Sodium*. Finding the simple light which a soda compound communicates to a flame, not of sufficient intensity for some researches in which an intense but perfectly homogeneous light was requisite, this experimenter tried the plan of burning the metal sodium in air, in the expectation that, as the combustion was accompanied with an extraordinary development of heat and light, a homogeneous light of the desired intensity would in this way be easily obtained. Upon trying the experiment, however, it was found that the light of the burning metal was quite different in its character to that known as the ordinary soda flame. The latter, when examined by spectral analysis, shows a luminous double line D on a dark ground; but the former was seen to emit a light which in the spectroscope appeared continuous from the red to the violet, with the exception that the line D stood out perfectly black on the luminous ground. This unlooked-for phenomenon, strange as it may appear at first sight, is, however, in strict accordance with theory. The fact that the bright sodium lines can be *reversed* or changed to dark ones by passing through a layer of heated sodium vapour is well known, and forms the fundamental point of Kirchhoff's theory of the constitution of the sun. The simple explanation of the black lines in the above experiment appears therefore to be, that the sodium compounds formed by the very rapid combustion of the metal were carried up into the flame in the solid state, and heated to whiteness, when they emitted light of every degree of refrangibility: a layer of ignited sodium vapour being in front of this continuous spectrum carved out of it the black lines.

Before we leave the subject of *Artificial spectra*, we may refer to a method lately given by Crookes, by which these can be observed in great perfection with very simple apparatus. The beauty and perfection of a metallic spectrum depends in general upon the heat of the flame. In order to bring

out some of the finer and characteristic lines, complicated electrical apparatus has hitherto been employed. Crookes, however, has shown, that by employing the metallic compounds in the form of chlorates, many, if not all, of these brilliant appearances can be produced with the ordinary gas flame. He describes the greatly-improved appearance which is thus obtained when baryta, strontia, lime, potash, soda, and lithia are examined in this way, the brilliant blue line of the latter metal being distinctly visible. The spectra of many of the heavy metals, which cannot usually be seen except with the electric light, can also be submitted to examination.

Professor Zantedeschi, of Padua, is of opinion that the lines in Fraunhofer's spectrum are not all fixed ones, but that some of them are variable. And the general tendency of recent examinations of solar and other spectra is to show that prismatic analysis is not of that absolute and unchangeable character as was at first supposed, but that it is subject, to a small extent, to conditions of temperature, &c.

M. J. M. Leguin has examined the spectra of phosphorus and sulphur by volatilizing those substances in a current of hydrogen. The vapour of phosphorus in hydrogen gives a red ray; an orange ray almost as visible as the red; two less distinct green rays at the more refrangible end of the visible part of the green; and, at a comparatively dark interval, a bluish-green ray; then some feeble blue or violet rays. Of these, the red and bluish-green rays probably belong to the hydrogen. In the sulphur spectrum there is a red ray, and three distinct and nearly equidistant green rays. The three green rays are the most prominent part of the spectrum of sulphur; they were seen with unmistakable precision in sulphuretted hydrogen and sulphurous acid.

The same investigator, in a note to the French Academy of Sciences, "On the Spectrum of the Electric Spark in Compound Gases," states that the spectrum of fluoride of silicium exhibits a large vivid blue ray, very far from the green; and the spectrum of fluoride of boron gives similar results; and he therefore attributes this blue ray to fluorine. He states that, whilst chemical decomposition is being produced in compound gases by the electric spark, the bands in their spectra are not distinct, and the spark is enveloped by a halo; but when the compound gas is nearly all decomposed, the spark becomes slender, and the bands in the spectrum much more distinct.*

The line of demarcation between organic and inorganic chemistry, sharp and well-defined up to a recent period, is now gradually disappearing. Organic chemistry was originally held to include all chemical compounds which required *vital force* for their production, whilst inorganic chemistry treated of all bodies which were capable of being built up from their elements by artificial means. Of late years the progress of science has placed us in possession of means of forming synthetically a vast number of purely organic compounds; and the International Exhibition contains, amongst the chemicals in the French department, some of the most remarkable products which have ever been formed in this way. M. Berthelot exhibits here, for the first time, alcohol, stearin, and other natural

* See also "Physics."

organic products, "per syntheticam artem generatum." As a starting-point, he takes a lump of charcoal and hydrogen gas, and actually forces these two bodies to unite and form the gaseous hydro-carbon, acetylene. This being obtained, he introduces the other elements by appropriate methods of treatment, until he arrives at substances of very complicated formulæ. These researches into the synthetical formation of organic bodies may, to the superficial observer, seem devoid of value; but it must be remembered, that by these researches, which M. Berthelot has for many years been carrying on, chemists are unfolding the laws by which Nature works in her vast laboratories of the animal and vegetable world; and when we remember the vast importance which would attach to the artificial production of such bodies as quinine and morphia, the most utilitarian will scarcely ask what is the use of these fascinating researches.

II. APPLIED CHEMISTY.

Schroeder has examined the effect of *filtering air through cotton-wool* in its relation to fermentation and putrefaction. The conclusion at which he has arrived is, that air in its ordinary condition contains germs which are removed by passing it through cotton-wool. Organic substances capable of putrefaction or fermentation likewise contain similar germs, which are, however, entirely destroyed by a more or less prolonged ebullition. If, after these have been thus killed, only filtered air is allowed to have access, no decomposition will take place, however long it be kept; but if some of these putrefaction-inducing germs are allowed to have access to the body, either by the ebullition not being sufficiently prolonged, or the air not being effectually filtered, decomposition will be sure to take place. The frequent failures in several domestic and culinary operations are thus easily explained. In making preserves or bottling fruit, for instance, the object is to destroy all the seeds of decomposition present in the fruit, and then to cover the jars tightly over with bladder or paper, so that none but filtered air can have access to it. The object of the preliminary boiling is, therefore, not so much to strengthen the preserve as to kill these germs; and the object of the covering with paper or bladder is not to keep the air from it, but to prevent the atmospheric seeds of decomposition from gaining access.

The process of *galvanizing iron pipes and surfaces*—that is, giving the metal a coating of zinc—is so commonly used under the impression that the zinc, by its polarizing action from contact, will preserve the iron from corrosion; and, as the oxide of zinc formed under such circumstances adheres to the metal and incrusts it with a body not soluble in water, it has been assumed that water passing through such pipes would not become contaminated by either iron or zinc. Dr. Hayes has recently found that this idea is incorrect. Water containing some very common organic impurities has been proved to have a decided solvent action upon both the iron and zinc; galvanized iron pipes exposed to this water not only dissolving in it, but the usually observed protecting power of the zinc was lost—the quantity of salts of both metals in solution being frequently so large as to render the water unfit for domestic use. It is a generally-received opinion that zinc compounds, when taken into the system, are not actively poisonous, if even

harmful. Dr. Hayes, however, has detected several cases of anomalous disease which could be traced to the habitual domestic employment of water so contaminated; and it is, therefore, strongly advised that, before galvanized iron vessels are used for the water-supply of a house, it should be ascertained whether there is any chance of the metal being corroded and dissolved.

It has long been a doubtful point whether *carbonic oxide* was really such a poisonous gas as some writers imagine. Although it is an almost invariable accompaniment of carbonic acid when produced by ordinary combustion, few persons have thought of ascribing to it a share in the calamitous results which have so frequently been caused by the inhalation of the vapours of burning charcoal. The lamentable accident at the Hartley Colliery first directed the attention of several physiologists to the subject, and the result has been that this gas must be now looked upon as a most violent and deadly poison; common air, containing as small a proportion as one per cent., proving rapidly fatal to rabbits and other small animals, and a half per cent. killing small birds in a few minutes. The action of this gas on human beings has frequently been demonstrated. Sir Humphrey Davy, after three inspirations of the diluted gas, fell down senseless, and upon recovering from this, it was succeeded by giddiness, sickness, acute pains, and extreme debility, which lasted for some days. Since then, Mr. Wilter as nearly as possible killed himself by an inhalation of the pure gas. He fell upon the floor in a state of perfect insensibility resembling apoplexy, and with a pulse nearly extinct; his life was only saved by his having pure oxygen gas forced into his lungs. On the Continent the employment of water-gas (a mixture of hydrogen with about thirty-four per cent. of carbonic oxide), as a means of illumination, has been forbidden by law, owing to the numerous fatal accidents which its escape into houses occasioned. These and several other instances, which have been collected together and examined by Dr. Letheby, prove without a doubt that the deadly properties of this gas have not been overrated; and as it has been also proved that this oxide is produced in the combustion of carbon whenever the supply of air is limited,—for instance, in brick-kilns, iron furnaces (about thirty persons having been poisoned at Clayton Moor from this cause), slow-combustion stoves, &c.,—it is important that the public should be well acquainted with the very dangerous properties of a gas to which they are liable by many accidents to be exposed.

An improvement in the *oxy-hydrogen light* has been effected by Mr. Fryer. The earth lime is generally employed as the incandescent body in this means of illumination; but there are several objections to its use which render the discovery of a more efficient substitute advisable. Magnesia has been found to give the best results, as far as light is concerned; but there was a difficulty in rendering it sufficiently coherent to resist the impact of the gases. After numerous experiments it was found that the best results were obtained by mixing together one part of sulphate of lime and two parts of calcined magnesia with water, moulding them into a cake and drying. The illuminating power, pressure and volume of gas being equal, is said to be exactly double that of lime.

Chloride of lime is daily used as a disinfecting and deodorizing agent; but its value as an insecticide is not so generally known: by scattering some of it on a plank in a stable, all manner of flies—even the biting flies—are quickly got rid of. Sprinkling beds of vegetables with even a weak solution of this salt effectually preserves them from the attacks of caterpillars, butterflies, mordella, slugs, &c.; and it has the same effect when sprinkled on the foliage of fruit-trees. A paste made of two parts of powdered chloride of lime and one part of some fatty matter, placed in a narrow band round the trunk of a tree, prevents insects from creeping up it. It has even been noticed that rats and mice quit places in which chloride of lime is occasionally spread. This salt, finely powdered, can no doubt be employed for the same purposes as flour of sulphur, and be spread by the same means.

A very ready *means of purifying chloroform* has been suggested by some experiments recently published by Hardy. Perfectly pure chloroform is not attacked by metallic sodium; but alcohol, wood spirit, hydrochloric acid, and other substances either intentionally added to, or spontaneously generated in chloroform by keeping, are at once acted upon by the alkaline metal with evolution of hydrogen, marsh gas, and oxide of carbon. This reaction takes place in the cold, and is almost instantaneous. After all disengagement of gas has ceased, the chloride of sodium and excess of metal remain at the bottom, and the chloroform, thus freed from foreign matters, is pure.

One of the most novel and important improvements which has been effected for several years in the *manufacture of lucifer matches* has lately been patented by Messrs. Bryant and May. The protection afforded by the use of this match is based upon the circumstance that it will only ignite upon the prepared surface of the box, no ordinary kind of friction being capable of inflaming the combustible materials with which the wooden splints are tipped. The match does not itself contain any phosphorus, but is coated merely with oxidizing substances, such as chlorate of potash in conjunction with binoxide of lead or manganese, and the ingredients are in this manner so divided that it is necessary to employ the special friction surface prepared with amorphous phosphorus in order to secure the inflammation of the match. The security against accidental conflagration is thereby reduced to a minimum; the splints have, indeed, so little of the dangerous character of the ordinary match that this manufacture enjoys the exclusive privilege of being sanctioned and admitted within the building of the International Exhibition. The matches are not coated with sulphur in the usual way, some kind of wax or fatty matter being employed for impregnating the wood. No phosphorus being employed in the match composition, they are, of course, quite free from the unpleasant odour and poisonous character of this substance. The dangerous practice of carrying loose matches in the pockets and about the house, and the common habit among servants of striking them upon the wall to the disfigurement of the paper-hangings, will be altogether avoided by the introduction of this match.

Mr. C. O'Neill has published some valuable experiments undertaken with a view to determine the origin of *paraffin-oil explosions*. The way in

which he tests the oil is to place about a quarter of an ounce into a six-ounce stoppered bottle, and, after inserting the stopper, shake the bottle well for three or four minutes; upon then removing the stopper, a lighted match is held to the mouth of the bottle; if there was a rush of pale blue flame through the bottle, the oil was said to give off an explosive vapour, and according to the temperature at which this test was performed the oil was said to be dangerous or ordinarily safe. Out of thirty-two samples two were found to explode at the temperature of 60° Fah., and were consequently highly dangerous. This temperature can, however, be only considered as the lowest limit of possible danger; the actual limit being a temperature as high as 85° or 90°, which may be calculated upon as often existing in the cistern of a lamp; this high temperature being produced by long-continued burning in a warm room and on a table near the fire. The experiment was, therefore, repeated at this temperature with the remaining samples of oil, when three more were found to be explosive; the other oils were then tested at temperatures of 100°, 120°, and 150°; four of them were dangerous at the first, three others at the second, and the remaining twenty at the highest temperature.

This is, however, beyond the limits of actual danger, and these twenty may therefore be looked upon as very safe oils. The classification of these oils presents several points of interest. They consisted of Young's Paraffin and American oils; the whole of the former were found to be safe, whilst only two American oils were safe, all the others exploding at or below 120°. It must, however, be remembered, that whenever the oils are scattered upon linen or woollen rags, at even the ordinary temperature of the air, they burst into violent flame upon a momentary contact with a lighted match or candle. This is the most dangerous property of mineral oil, and in it there is no considerable difference between Young's best samples of paraffin oil and the worst American oils. Before a fresh sample of paraffin oil is purchased for domestic illumination, it should be tested in this way. The proper temperature can be readily communicated to the bottle and oil, by immersing it in water at 120°, and no oil which gives off an explosive vapour at that temperature should be allowed to enter a dwelling-house. The real danger to society consists in the practice of selling one species of oil for another; *genuine paraffin oil is perfectly safe in a proper lamp; but the majority of the American substitutions are scarcely safe under any circumstances.*

GEOLOGY AND PALÆONTOLOGY.

ONE of the most noteworthy of modern geological discoveries is a strange animal, half reptile, half bird, from the Lithographic slate of Germany. Covering a slab of about one foot and a quarter square, the remains indicate a creature abundantly feathered. A single feather like those of the common partridge, showing the quill and all the fibres of the vane beautifully preserved, had been previously described from the same deposit by Von Meyer; but this fossil, unlike any bird, has the feathers, which likewise show stem and vane, at the extremity of the arm (the hand not being preserved)

radiating like a fan; and those attached to a long tail of twenty vertebræ, radiating laterally so as to form a leaf-like shape broadest at the terminal end. The head and neck are unknown. The feet, like those of birds, consist of a strong tarsus of one bone, trifid at its lower end for the attachment of three toes, which terminate in strongly hooked claws. But, unlike a bird, the joints of the lower part of the back, instead of being united into a large bone called the sacrum, all remain separate; and the pelvic bones, into sockets in which the thigh-bones work, instead of being large and extending along the sacrum as in birds, are small, and like those of the Pterodactyle. A further peculiarity is the length of the tail, which contains twice as many vertebræ as that of a bird, and, what is more important, gradually tapers to the end instead of terminating in a bone larger than the others. Until more is known of it, and its structure has been carefully compared with that of other animals, nothing but a guess can be given as to whether it is bird or reptile; Von Meyer seemingly inclines to the former view, and names the genus Archæopteryx; Dr. Wagner, however, thinking it a reptile, gave it the name of Griphosaurus. Should the latter supposition prove correct, it will furnish one more illustration of the fallacy of Cuvier's doctrine that an unknown creature can be restored from a single bone; for, had the tarsus only been found, it would as surely have been referred to a bird, as the similar bones from the upper greensand of England.

At a late meeting of the Geological Society, Sir W. Logan exhibited a plaster cast of some remarkable impressions found at the base of the Cambro-Silurian rocks, in the Potsdam Sandstone of Canada. These markings, certainly the trails of some animal, are about six inches wide, with the sides parallel and elevated like a tramway, and extend uniformly over the slab for several yards, sometimes straight and sometimes curved; only a central ridge appears wherever there is a bend. But what is most singular is, that at distances of about two inches there are transverse ridges, the spaces between which are inclined planes deepest in the direction from which the creature was going; so that the trails resemble more than anything a narrow Venetian blind when shut. Nothing whatever is known of the animal except the story told by its tracks. The cross-bar ridges show that it did not move smoothly and uninterruptedly like the hedgesnail and most other molluscs, but with a uniform jerking motion, which suggests the probability of its being a crustacean. The tramway-like ridges which are due to the weight of the body drawn over the sand indicate an animal without hind limbs to support the tail. The inclined depressions behind the cross ridges will suggest that motion was made chiefly by a pair of limbs about the head which were used together, so that by elevating the front part of the rather rigid body the tail was pressed into the sand, when the creature would draw itself along rapidly till its whole length rested on the sand again, just as would a child, trying to move similarly; hence the tail would be drawn out of the depression it first made, then impressed again, and so on. Judging from the short distance between the cross-bars, the legs must have been short. To have made the median ridge visible in the bends, the tail would have been provided with a pair of side-flaps like those in a lobster, which would readily straddle apart as the animal turned round, allowing the sand between to rise in a ridge. All these characters render it likely that the

genus was nearly related to the group Eurypterida which occurs in newer Palæozoic rocks.

Professor Owen has described five new small reptiles from the coal of Nova Scotia, which, from their size and teeth, are supposed to have been insectivorous, so that, could it have been preserved, one might expect to find an abundant insect fauna in these old rocks.

Professor Heer, after a careful study of the plant remains from the uppermost Eocene of the Isle of Wight, has decided that, like the Bovey-Tracey coal of Devon, the beds should be classed as Lower Miocene. It is important, however, as suggested by Professor Ramsey, to remember how slight our knowledge of fossil plants yet is, when it is brought forward to override evidence of the immeasurably better known group of fossil shells. The molluscan remains had scarcely suggested a doubt as to the Eocene age of the deposits; hence it is far from unlikely that the final result of these conclusions by Professor Heer will be to remove into the older formation many beds now believed to be Miocene.

In a new species of Eurypterus from the coal-measures, Mr. Salter finds the sides of the back ornamented with ramifying spines looking like miniature trees, a character which, besides being very beautiful, is interesting as the only case of its kind known in the animal kingdom.

Among the reptilian fossils brought by Prince Alfred from South Africa, is the pelvis of a large Dicynodon, in which the three bones on each side are, as in mammals and some lizards, anchylosed, or united into one bone, forming a strong support for the hind legs; but the anchylosis has gone further than in any mammal, for the two *Ossa innominata*, as these bones are called, are united into one strong hoop. From the strength of this remarkable pelvis on to which the ribs abut, Professor Owen anticipates that, when found, the hind limbs will be large,—keeping the body well off the ground. It may be remarked that this genus has another mammalian resemblance in its two walrus-like teeth.

In the Rániganj coal-field in India, which is by far the most important, there are 49 collieries, many with several workings, about one half of which are ordinary quarries and the others pits. The thickness of the seam varies from 5 to 35 feet, and except in the thickest deposits the whole depth is worked. This coal is considered by Dr. Oldham (Superintendent of the Survey) as Triassic, on the grounds that it contains a single minute crustacean (Estheria minuta), common in the Trias of Europe; that among the genera of plants, which for the most part range through the Secondary and Carboniferous rocks, there is one hitherto only found in the Trias, and also that Dicynodont and Labyrinthodont reptiles have been found, such as occur in strata in Africa, supposed to be Triassic. It is possibly of this age, as it might be of any other. But the biologist remembering that distribution in space is the index of correspondingly long duration in time, will not regard the age as so well determined that it can be used as a datum for interpreting the much-disputed age of the Australian coal-measures which have some fossils in common.

Captain Playfair, of Aden, reports a volcanic eruption near the Straits of Bab-el-mandeb in May last, accompanied with earthquakes, in which the sky became pitch dark, and the volcano ejected first fine white dust, and after-

wards a red dust which fell knee-deep. The dust continued to fall for several days, and some distance out at sea. At night the mountain Jabel Dubbeh, a day's journey inland, was seen giving out smoke and fire.

In the succeeding August a steamer crossing the Caspian found in its middle a newly-elevated island some 200 feet long and six feet high. The ground, which smelt strongly of petroleum, was still quite soft and difficult to walk on, from the feet sinking in.

In the December following came the eruption of Vesuvius, pouring out one more of the many lava coats which have made up its mass. Preceded by more than twenty distinct earthquake shocks, at mid-day on the 8th, the sky became completely dark over the Torre del Greco, and clouds of ashes were projected out from several jets on the sides of Vesuvius; in the night ashes were succeeded by lava, which in the next morning had so hardened as to bear walking on, though the interior was so hot that a stick put into the cracks took fire. On M. P. de Tchihatcheff approaching the smoking hills, he saw the glowing scoriæ, black ashes, and white steam, thrown out with intermittent shocks resembling the puffs of a steam-engine. The explosions of the new craters, as well as the flow of lava, almost ceased about the third day; but in the mean time the central cone of Vesuvius, previously tranquil, began ejecting ashes and steam in dense clouds, which on the 23rd fell abundantly in the streets of Naples,—an event which has not occurred since 1822. There were in all about twelve new craters formed.

At the same time the shore beneath Torre del Greco was permanently elevated about four feet,—a long line of shells and zoophytes being now raised that height above the sea-level.

MECHANICAL SCIENCE.

EFFORTS have been made at various times since the introduction of railways to reduce the friction of the wheels of the carriages, and so to diminish the tractive resistance which the engine has to overcome. The failure of tyres, leading to frequent and fatal accidents, has of late drawn increasing attention to the subject, and various attempts have been made to remedy the defects of our present system of construction. Friction-wheels for bearings have been tried on the Eastern Counties Railway. Steel wheels and wheels with steel tyres have been adopted to some extent, and Mr. Bridges Adams has invented an elastic wheel, having a spring between the run and tyre, which exhibits great durability. Meanwhile M. Gerard proposes to abandon wheels altogether, and his plans have been experimented upon at the expense of the French emperor. He places the carriages upon sledges, which are hollow, to receive water forced in under pressure: this water passes in a minute film between the sledge and rail, so that the carriage rather *floats* than *slides*, and the tractive resistance is said to be very small. Further experiments under the direction of a commission are contemplated.

Machinery worked by compressed air, like that on one side of the Mont Cenis tunnel, alluded to in our last number, has been employed in hewing coal in a pit near Ardsley, under a patent of Messrs. Donisthorpe, Firth, and Rothery. The air is compressed by a powerful steam-engine at the pit's mouth to 50 lb. per square inch, and thus conducted in bitumenized pipes a

distance of nearly a mile to the cutting machinery. Having worked the pick or cutter, which is under the direction of a single man, the air escapes at every stroke and materially improves the ventilation of the mine. No more legitimate or beneficial application of machinery could well be conceived, nor one more likely to meet with ultimate success than this, which promises to reduce the hardships of a laborious and dangerous employment, and one (in spite of remarkable exceptions) not very favourable to the mental or moral development of the workers.

This year seems likely to be marked by the general adoption of the steam-plough. Machinery has already been applied to all the indoor operations of the farm, but in the field its progress has been slower. Nevertheless, reaping and mowing machinery is in great request, and the steam-plough is at last receiving the attention it deserves.*

MICROSCOPICAL.

MICROSCOPIC Life in the Island of St. Paul.—The veteran Ehrenberg has published a paper on this subject, the result of investigations made by the *Novara* expedition at the suggestion of Von Humboldt. The island, situated far out in the Southern Ocean, between the Cape and Australia, is two miles by three in size, and its remarkable position and isolation, and purely volcanic origin, render it highly interesting.

The samples examined by Ehrenberg were specimens of stones from a hot spring, cinders from the coast, coarse black sand, probably magnetic, moss-turf, and earth beneath the turf. In some sand from the hot place close to the shore of the crater basin, he found two Polygastria and three Phytolitharia in an isolated condition. One hundred and fifty-four forms of organisms were met with, of which one hundred and nine were silicious, sixteen calcareous, and twenty-nine soft forms. Nearly half of the whole were independent organisms, and the remainder characteristic parts only, as of grasses and sponges, and twenty-nine were new to the Professor. He believes that in this island an abundant, earth-forming, invisibly powerful organic life is going on.

Revivification of Tardigrada and Rotatoria.—A remark by Professor Ehrenberg is worthy of notice. Among the microscopic forms from St. Paul were some of the above organisms. He says, "I immediately tried with great care whether they would give signs of life in water, or whether they could be brought into full vital activity, which has usually been erroneously described as a resuscitation from death. The dry materials which were collected in December, 1857, and reached me in 1861, and were consequently more than three years old, exhibited no signs of vitality in any of the forms in which these were expected, although in previous experiments with materials from other localities, I had been able to observe life still retained even for four years. We can revive no dead organisms, even the smallest!"

* See Reed's article on the "Agricultural Department of the Great Exhibition," p. 407, in the present number.

Antiquity of Desmideæ and Diatomaceæ.—An examination of the hornstone nodules of the Devonian and Silurian rocks of New York has resulted in the discovery of abundant organisms referable to the Desmideæ, such as numerous forms of Xanthideæ, supposed to be the sporangia (1) of Desmids, and an occasional duplicated (2) Desmid; and lines of cells, some of which appear to be sparingly branched. Besides these were found a few Diatomaceæ. It is observed for the use of those who undertake the investigation of siliceous concretions, that the use of turpentine renders the chips of chert (3) almost as transparent as glass.

Entry of Minute Organisms through the Pores of the Body.—Mr. Carter of Bombay thinks there is reason to believe that the Guinea-worm is a monstrous development of some minute species of free Filaridæ (4), and that these little creatures having a calibre much smaller than the ducts of the sudorific gland, probably pass through those apertures into the human body. He has found them entering thus through the even minuter apertures of a species of Sphæria (5). So also the black Fungus disease of India, as he thinks highly probable, may arise from the entry in the form of a Zoospore, of a species of Mucor (6), through the sudorific ducts.

Foot of the Fly.—Mr. Tuffen West, in an elaborate article in the Linnæan Transactions, has most carefully examined and described this remarkable and complicated organ. With regard to the vexed question of the insect's mode of walking back downward on smooth surfaces, he says, "When a fly is not making use of its pulvilli, as on a surface sufficiently rough to afford it foothold with its *claws* alone, they only are made use of. On a smooth surface, however, perpendicular or horizontal, the pulvilli are brought down, and certain *tenent hairs* (so called because they are the immediate agents in holding, and which project from the inferior surface of the flaps at the base of the claws), are applied to such surface. A slight push forwards of these, succeeded by a gentle draw backwards at each application, removes the air between their soft elastic expansions and their plane of motion, and thus a firm hold is gained. Access of air is prevented by the minute quantity of air which exudes from the expanded tips of the tenent appendages; and thus a vacuum is formed, on the same principle as in the "Atmospheric Hat-peg," or "artificial gums" of the dentist. When the fly wishes to remove a leg from its place of attachment, the claws are brought down and pressed against the surface; from their position they raise the hinder part of the pulvillus, where the tenent hairs are least developed, first, and so on forward. A fly, when once stuck fast, if it had no claws, might remain so. The pressure of the atmosphere is thus the main agent which enables the fly to adhere to perfectly smooth surfaces. The atmospheric pressure on the area of the flaps alone is calculated at just one-half the weight of the fly, that on the tenent hairs at one-fourth more. Mr. West accounts for the remaining fourth by the slight viscidity of the fluid (*sudor*), by grasping, and other delicate and subtle agencies.

Mounting Polyzoa, &c.—The difficulty of showing Polyzoa and Hydrozoa with outstretched tentacles, under the microscope, has been overcome by Mr. J. W. Morris, of Bath, by adding spirits of wine, drop by drop, to water in the cell containing the living animals, which causes them to unfold their arms, and in that condition die. Thwaits' fluid is also recommended.

Structure and Growth of the Tissues.—Dr. Beale in his recently concluded Lectures before the College of Physicians, maintains that every living structure, and every elementary part that is living, is composed of matter which is *forming* and matter which is formed—germinal matter and formed material. He remarks that the *nucleus* of the frog's blood-corpuscle is *germinal* matter, the external red portion (cell-wall, and coloured contents) *formed material.* That the white blood corpuscle, the lymph and chyle corpuscle, and the pus and mucus corpuscle are composed entirely of germinal matter, with a very thin layer of formed material; the viscid matter or mucus between the mucus corpuscles is formed material. The nucleus of an epithelial cell is germinal matter—and in a fully-formed cell, the outer part, cell-wall, or cell-contents, consist of formed material; and so on.

Museum Microscope.—Messrs. Smith & Beck, who are constantly exerting their ingenuity in some new application of the microscope, have exhibited to the Microscopical Society a microscope, under this name, adapted for use in public places, where it may be handled by persons unaccustomed to its use, without fear of destruction or damage. It consists of a microscope-body fixed upon a cylinder of brass which rests upon a cast-iron frame. The brass cylinder has a large series of slides arranged upon smaller cylinders, which by turning a milled head are brought successively before the eye. Moreover, this microscope by a simple adjustment is readily adapted to either of three different powers with which it is supplied.

NOTES.

1 & 2. The Desmideæ are microscopic green Algæ, the germs or capsules of which are termed "sporangia." The cells are formed of two symmetrical valves, the junction being marked by a division of the green tissue. Hence they are termed *duplicated.*

3. Chert, a granular variety of quartz.

4. Filaridæ, microscopic parasitic worms found in the fluids of the body, as in the blood, chyle, and humours of the eye.

5. Sphæria, a very large genus of fungi, of which several hundred species are described.

6. Mucor, a sort of mouldiness, consisting of vegetable cells of a parasitic nature.

7. Pulvillus, a soft, membranous, cleft cushion, situated on the under surface of the fifth tarsal (or ankle) joint of the fly.

MINERALOGY AND METALLURGY.

A PAPER was read a short time since at the Chemical Society of London, by Mr. Frederick Field, upon the "Universal Distribution of Bismuth in the Minerals of Copper containing Sulphur." From an extensive investigation upon the composition of commercial coppers from all parts of the world, conducted by Messrs. Abel and Field, in the majority of which bismuth was detected in very sensible quantities, Mr. Field determined to submit a vast number of copper ores to minute analysis, in order to arrive at a satisfactory conclusion from whence bismuth was derived. Specimens were obtained from various localities in England, Scotland, Ireland,

Wales, France, Spain, Turkey, Russia, Africa, Australia, Chili, Bolivia, Peru, Mexico, and the Northern and Southern States of America. In all the sulphides of copper from these countries, bismuth was deteced; but in the malachites and oxides from Australia it was absent.

The increased working of the *mines in Chanaral, Northern Chili*, has developed enormous quantities of the oxy-chloride of copper, a mineral looked upon hitherto as somewhat rare. One of the mines in that neighbourhood has also been very productive of the black oxide, found heretofore in comparatively small masses.

The smelting operations in Chili have been extraordinarily increased during the past year, and the shipments of copper ores have been very large. More than 30,000 tons of copper, in bar, regulus, and mineral, were exported from that country in the year 1861.

Dr. Percy's second volume is expected to appear about December. The author is engaged in many important experiments on the metallurgy of iron, which are looked forward to with much interest.

The Composition of Furnace Regulus.—Mr. Field has written a paper upon "The Composition of Copper Regulus." He had entertained the idea for some years that the first products of the copper furnace had a definite chemical constitution, although they were supposed by the majority of chemists to be simple admixtures of copper, sulphur, and iron, in variable proportions. Mr. Field asserts that one or more equivalents of disulphide of copper ($Cu_2 S$) are associated with one of the sesquisulphide of iron ($Fe_2 S_3$), one of the protosulphide (Fe S), and two of the disulphide ($Fe_2 S\delta$), in confirmation of which idea he publishes many analyses, among which one or two may be cited.

A well-roasted sample of regulus gave—

Copper	61·34
Iron	15·61
Sulphur	22·90
	99·85

A very fine specimen of copper pyrites gave—

Copper	54·21
Iron	21·43
Sulphur	24·12
	99·76

Experiments on Amalgams.—At a recent meeting of the Literary and Philosophical Society of Manchester, Dr. Joule communicated some very interesting facts on the combinations between mercury and other bodies.

The weakness of the affinity which holds the constituents of amalgams in combination seemed to the author to offer the means of studying the relationship between chemical and mechanical force. His inquiries were extended to several amalgams, and gave results of which the following is a summary :—

Amalgam of iron was formed by precipitating iron on mercury electrolytically. The solid amalgam containing the largest quantity of

mercury appeared to be a binary compound. Iron does not appear to lose any of its magnetic virtue in consequence of its combination with mercury. Its amalgamation has the effect of making it negative with respect to iron in the electro-chemical series. The affinity between mercury and iron is so feeble that the amalgam is speedily decomposed when left undisturbed, and almost immediately when agitated. The application of a pressure of fifty tons to the square inch drives out so much mercury as to leave only 30 per cent. of it in the resulting button.

Amalgam of Copper. By precipitating copper on mercury electrolytically, a mass of crystals is gradually formed. After a certain time the crystals begin to get fringed with pink, indicating uncombined copper. In this state the amalgam is found to be nearly a binary compound. On applying strong pressure to an amalgam containing excess of mercury, the latter is driven off, leaving a hard mass composed of equivalents of the metals; if, however, the pressure be continued for a long time, the resulting amalgam contains more than one equivalent of copper, indicating a partial decomposition.

The author gave an account of his experiments with amalgams of silver, platinum, lead, zinc, and tin. In the case of the latter amalgam, long-continued pressure drives off nearly the whole of the mercury, indicating in a striking manner the efficacy of mechanical means to overcome feeble chemical affinities.

A new Fusible Alloy.—Dr. Wood, who has investigated many of the alloys, has just published a description of a new and interesting fusible alloy. "In the *American Journal of Science and Art* for September, 1860," Dr. Wood says, "will be found a notice of the cadmium alloy, discovered by me, consisting of from one to two parts of cadmium, two parts of tin, four parts of lead, and from seven to eight parts of bismuth, and so exceedingly fusible as to melt below the temperature of 160° Fahr. A brief description of another alloy, similar in character and scarcely less remarkable, is herewith submitted; it consists of cadmium, one part; lead, six parts; bismuth, seven parts. This alloy melts at about 180° Fahr., being nearly midway between the melting-point of the old fusible metal, consisting of the three metals, tin, lead, and bismuth, and that of the alloy first mentioned, consisting of the four metals, cadmium, tin, lead, and bismuth. It is remarkable, as exhibiting the liquefying property of cadmium in certain combinations; also in the fact that, while the mean melting-point of the constituents composing it is much higher than that of those composing the old fusible metal, it melts at a much lower temperature, being more fusible than any other alloy yet known consisting of but three metals. It has a clear, brilliant, metallic lustre, that does not readily tarnish. Its colour is a bright bluish grey, resembling platinum; when cast, its free surface presents a white frosted appearance. It is very flexible in thin plates, and breaks with a hackly fracture; but when thicker bars are broken, the fracture is smooth, resembling that of tempered steel. It is malleable, but not perfectly so. Its hardness is about the same as bismuth, and about the same as an alloy of two parts of lead and one part of tin or coarse solder, which it more nearly resembles in other respects. It may be that more approved methods of measuring temperature will give

the alloy a still lower melting-point than above ascribed to it, as I see that the experiments made by Lipowitz with my fusible metal indicate for it a much greater fusibility than my measurements."

The improved processes for the manufacture and metallurgy of *platinum*, by M. St. Claire Deville, are now generally known to the scientific public. The process is based upon the employment of a gigantic oxy-hydrogen blowpipe playing upon the metal in a nearly closed chamber cut out of lime, and was almost immediately upon its introduction adopted by the firm of Johnson, Matthey, & Co., the well-known precious metal refiners, who have since used it largely in the manufacture of platinum. They have recently availed themselves of the presence in England of M. Deville and other eminent scientific men to invite a party of English and Continental *savans* to witness one of the grandest metallurgical feats ever accomplished,—the melting and casting of a mass of pure platinum weighing upwards of 2 cwt. This mighty ingot of precious metal, by far the largest mass ever before obtained in a single lump, and worth £3,840, has recently been deposited in the International Exhibition. The mould into which it was run was roughly built up of refractory limestone; and the extreme fluidity of the liquid metal is well illustrated by the irregularities in the sides of the ingot, it having entered the minutest crevices between the lumps of stone as if it had been so much water. The sharpness of the impression, and the minute details which the melted metal has retained on solidifying, show that platinum, when once obtained in a fluid state, is as eminently adapted for fine castings as any of the commoner metals. We regret to add, that the vapour of osmic acid was given off so abundantly in this operation as to seriously affect M. St. Claire Deville, who superintended the fusion. He was obliged to return to Paris, where he for some days suffered severely.

PHOTOGRAPHY.

THE duties of the jury in Class 14, Photography, in the International Exhibition, are likely to be very onerous, on account of the large assortment of excellent photographs and apparatus displayed, not only in the British Department, but throughout all, or a large majority, of the foreign and colonial courts. The art of photography constitutes one of the chief efforts of science which has advanced with giant strides since the period of the Exhibition of 1851. With the introduction of the collodion process, which dates from the latter part of that year, and was actually employed by its inventor, Mr. Archer, within the building in Hyde Park, so much has been already accomplished that the World's Mart teems with innumerable examples of its successful application. The records of astronomical and meteorological phenomena, the adaptation to portraiture and to the illustration of foreign races, their manners and customs, remarkable landscape scenery, and the characteristics of distant regions,—on every side the visitor to the International Exhibition is reminded of the vast importance of photography, and of the attention it must have received during the intervening ten years. We are enabled to admire the results of our continental rivals, and to compare the life-size portraits of Mr. Mayall and other British exhibitors with those taken by M. Hansen, of Copenhagen.

The excellent photographs of MM. Ghémar Frères, and of Oehme and Jamrath, of Berlin, and the panoramic views of Florence, are well worthy of close inspection; and there is much to admire also in the way of photographic apparatus and chemicals of foreign manufacture, especially the cameras of M. Emile Busch, of Potsdam, and the monster sample of finely crystallized pyrogallic acid sent by M. Schering, of Berlin.

The expenditure of silver in the photographic processes has been lately made the subject of investigation by Mr. W. T. Mabley, who has communicated the results of his experiments to the Manchester Photographic Society. It appears that in the preparation of a full-sized sheet of sensitized albumen paper no less than sixty grains of nitrate of silver are withdrawn from the solution when of the strength of seventy grains to the ounce of water; but by careful management a very large proportion of this amount may be recovered in the form of insoluble salts of silver, such as the chloride and sulphide, which may again be reduced to metal. Mr. Mabley states, as the result of his operations upon fifteen sheets of albumenized paper, that he succeeded in collecting 350 grains of chloride of silver from the nitrate washings of the prints, and 180 grains of metallic silver reduced from the hyposulphite fixing-bath. If from these numbers the average saving be calculated, it will be found that more than three-fourths of the silver originally employed in the preparation of the paper should be recovered in the form of residues. In the course of his statement, Mr. Mabley describes a novel method of detecting and precipitating small quantities of silver from the hyposulphite solutions. It consists in adding caustic soda until alkaline, and boiling with a little grape-sugar, when the least trace of silver in the liquid will manifest its presence by the formation of a metallic deposit of reduced silver.

A series of comparative experiments are recorded in the "American Journal of Photography," which have for their object the determination of the relative degrees of sensitiveness possessed by albumenized paper which has been treated with the plain nitrate and with the ammonio-nitrate of silver. Paper prepared with the latter agent is shown to be more readily affected by light, and easily toned; but there are, at the same time, some disadvantages attending the employment of ammonio-nitrate of silver with albumen, in consequence of which it is recommended to sensitize the paper by floating upon a neutral solution of nitrate of silver, and afterwards to expose the dry sheets to the fumes of concentrated ammonia in a large glass bottle or cylindrical jar.

The American operators have likewise been experimenting upon new materials for the construction of the dipping-bath used in the collodion process. Glass, porcelain, gutta-percha, and, more recently, ebonite, have been successfully employed; but the last idea is to try the application of wood: the result has proved a failure on account of the decomposing action exerted by the salts in the wood upon the solution of nitrate of silver.

It is the common misfortune of photographers to experience a difficulty in preserving the nitrate bath in the most sensitive condition, without exhibiting a tendency to produce "fogging" on the development of the collodion picture; and when this condition is practically realized, the most trivial disturbing cause will often overturn that nice degree of neutrality

upon which the successful result so much depends. In order to restore to proper working order a bath which exhibits these erratic properties we should do well in following the instructions of Mr. Divine. The silver solution is to be transferred to a glass vessel, and freely exposed to the sun's rays, when any contamination arising from the presence of oxidizable organic matter, or from an excess of the oxide of silver itself, is quickly destroyed with reduction of dark-grey metallic silver; at this stage a small quantity of a dilute solution of common salt is introduced, which will have the effect of carrying down with it these finely-divided particles, which no ordinary filter is capable of separating. After thorough agitation the liquid may be filtered, and the clear solution returned to the dipping-bath.

The preparation of pure nitrate of silver for photographic purposes is in some cases facilitated by employing ammonia as a means of separating traces of copper from reduced metallic silver. In proceeding to make use of this plan, the silver and copper alloy (standard silver) is to be dissolved in nitric acid, and the clear solution precipitated by common salt, when a moderately pure form of chloride of silver is obtained after careful washing. This precipitate is then dissolved in ammonia, and again thrown down in the state of reduced metallic silver by the action of a rod of copper; by washing now this finely-divided silver with dilute ammonia, every trace of copper is removed, and the pure metal may be dried and dissolved at once in nitric acid; the solution being either evaporated to the crystallizing point, or carried to dryness and partially fused, to furnish the neutral description of nitrate of silver.

The use of the proto-salts of iron, as developing agents in the collodion process, appears once more to be gaining the ascendancy over pyrogallic acid. M. Adolphe Martin has given an excellent suggestion for the removal of the small quantity of free sulphuric acid which is usually contained in the crystals of proto-sulphate of iron, and which interferes with the production of delicate half-tones when this agent is used in the preparation of a developing solution.

Acetate of lead is weighed out in the proportion of one part to four of the sulphate of iron, and these salts being separately dissolved in water are mixed, when a heavy precipitate of sulphate of lead is formed with production of an equivalent amount of the acetate of iron. Under these conditions it is impossible for any free sulphuric acid to exist in the solution; a small quantity of acetic acid will be liberated, which serves a useful purpose in keeping the iron dissolved without hindering its developing qualities.

With a similar object, a writer from Elberfeld recommends the addition of nitrate of potash (saltpetre) to the sulphate of iron developing solution. This expedient was, however, suggested as far back as 1853, in the "Journal of the Photographic Society," by Mr. Spiller, who described this as a ready means of preparing a solution having all the properties of the proto-nitrate of iron, and capable of developing the half-tones in great perfection.

PHYSICS.

LIGHT, PHOSPHORESCENCE, AND HEAT.

THE subject of prismatic analysis still continues to attract attention. Dr. W. A. Miller has been lecturing on this subject to the Pharmaceutical Society of London, and Dr. Roscoe at the Royal Institution of London and elsewhere.

Some degree of variability, if it may be so expressed, has been observed by several investigators in the *spectra of the earthy alkalies*, on subjecting those substances to high and variable temperatures, and this variation has been examined by Professors Roscoe and Clifton, and the explanation they suggest of this variation is, that at the temperature of a gas-flame the spectrum of the *oxide* of the substance is seen, whilst at the higher temperature of the voltaic arc the oxide is decomposed and the spectrum of the elementary substance itself is seen.

M. Morren has been examining the *phosphorescence of rarefied gases* and finds—,1st, that pure and dry oxygen, however rarefied, is never phosphorescent by the passage of electric sparks; 2nd, that any other gas, whether simple or compound, if pure and rarefied, never shows the phenomenon of phosphorescence; 3rd, a mixture of oxygen and nitrogen exhibits feeble and transient phosphorescence, and more distinctly if a little vapour of ordinary nitric acid is added; but if a small quantity of either fuming or anhydrous sulphuric acid is added, the phosphorescence is splendid and durable; 4th, a similar beautiful result is obtained by passing induction sparks through a rarefied mixture of 200 parts oxygen, 150 sulphurous acid, and 100 nitrogen; and, 5th, the phosphorescence is produced by the decomposition and recomposition of the crystallized body produced in the manufacture of oil of vitriol; viz., NO^3, 2 SO^3. Anhydrous sulphuric acid is probably the seat of this luminosity.

The subject of phosphorescence has also been recently investigated by M. O. Fiebig, particularly with regard to the influence of heat upon this property of bodies. He has found that when a solution of aesculine is gradually heated, the blue tint first becomes deeper and more violet, then it becomes paler, and at about 50 degrees it can hardly be distinguished from the ordinary tint. By further heat, the tint lessens in intensity and becomes pale green, and that, with a solution of quinine similarly treated, the tint lessens in intensity as it approaches the boiling-point; and, in both liquids, cooling reproduces the original colour. He also found that fluoride of calcium possesses the property of becoming phosphorescent by the action of heat after a previous insolation, and that this property remains after the loss of colour.

Professor Rankine, of Glasgow, has described, in the *Philosophical Magazine*, a dew-bow, which he saw on the surface of mud, in a by-road near Glasgow, on the 13th of February last; he states, "that its colours were complete from red to violet, and very bright and distinct, especially where the mud was softest and moistest; where a sheet of water, how thin soever, covered the mud, the iris vanished. No trace of an iris could be seen on the grass, in the sky, or anywhere but on the mud; and on those

parts of the turnpike-road where the mud had been much disturbed no iris was visible."

A French Academy Commission, composed of Becquerel, Despretz, Combes, and Pouillet, have recently examined and commended M. Serrin's newly-invented regulator for electric lights.

Heat.—No. 12 of Poggendorff's "Annalen" contains an article "On the Passage of Radiant Heat through Moist Air," by Professor Magnus, and this paper has been translated and published in the *Philosophical Magazine.* The author states that "neither by the application of a source of heat of 100, nor by using a strong gas-flame, could any difference be perceived in the transmission of heat through air, whether it was dry or saturated with vapour." In consequence of results contradictory to these having been obtained and published by Dr. Tyndall, the author has repeated his experiments and reiterates his former statement, "that aqueous vapour, so long as it is not separated as fog, exercises at 15 C° no appreciable influence on the transmission of thermal rays, and that the rays of the sun, so long as the air is clear, reach the earth in the same manner, whether the atmosphere is saturated with vapour or not." Dr. Tyndall explains, in a succeeding paper in the *Philosophical Magazine*, the manner in which he considers the difference of the results in the two cases occur.

Drs. Matthiessen and Von Bore, in their experiments "On the Influence of Temperature on the Electric Conductivity of the Metals," have come to the conclusion that "all pure metals, in a solid state, vary in conducting power to the same extent between 0 and 100 C," and that "metalloids conduct electricity better when heated than when cold."

ZOOLOGY.

THE Hominal Kingdom.—Dr. Fée, of Strasbourg, has entered into a controversy with M. De Quatrefages, who was supported by the recently deceased Isidore Geoffroy St. Hilaire, with respect to the separation of *man* from the other mammalia, which was suggested by the last-named, on the ground that Man possesses moral and religious sentiments (*moralité et religiosité*) which are peculiar to him, and are possessed by no other animal. Dr. Fée adopts the position, that if the intellectual faculties were to be taken as a standard, it would be necessary to re-classify the whole animal kingdom; insects would have to be placed before fishes, birds before most mammals, &c. He argues that it is not proved that the brain of man is different in its character from that of animals; that some men are hardly more capable of education than some animals, and, therefore, that a human kingdom is inadmissible.

European Apes.—The Rev. A. C. Smith, having recently visited Spain, made particular inquiry concerning the presence of the Barbary ape (*Macacus inuus*) upon the rock of Gibraltar. Undeceived by the incredulous tone of a French skipper, who professed that no such animals existed, he applied for information to the signal-man posted at the top of the rock. This man declared having seen them that very morning "on the move,"

the shifting of the wind inducing them to seek the most sheltered side of the rock. They appear to feed upon the sweet roots of the palmetto (*Chamærops humilis*) and on beetles and other insects. Their numbers, however, are rapidly decreasing, and unless means are soon taken to perpetuate their race upon the rock of Gibraltar, the quadrumana will speedily cease to be a European order. For some years past they have been watched, and the register shows that their numbers, which amounted to ten in 1856, are now reduced to four, which there is reason to believe are, moreover, all of the same sex.

The Gorilla.—The wonderful adventures of M. du Chaillu in Equatorial Africa having been for a brief period the all-absorbing topic, have, like other nine-days' wonders, subsided into their proper place. The retirement of M. du Chaillu himself from the field of controversy has allowed judgment to go by default, and the reception given to his book by those traders upon the Gaboon who are best capable of judging of its merits and credibility, has gone far to aid the public in forming a correct estimate of the matter. A letter in the *Times* of June 3rd, forwarded by Sir R. Murchison, revives the subject; but, being only a general testimonial of previous good conduct, it has but little bearing upon the present issue, and the evidence brought forward is only of a negative kind. At the same moment, by a curious coincidence, Mr. R. B. Walker has arrived from the Gaboon, bringing with him some most remarkable remains of the giant ape, which we have had the pleasure of inspecting in the Liverpool Museum. These consist of a head, hand, and foot, preserved in spirits, which give a more correct idea of the formidable character of the animal than any specimens hitherto exhibited. The head measures fourteen inches from the muzzle to the nape, and the hand and foot must be seen to be appreciated. They are destined for the British Museum. The monster to which they belonged must have stood six feet high. Two skeletons have been generously presented by Mr. Walker to the Liverpool Museum. The thigh-bone of one of these measures sixteen inches and a quarter in length, or two and a half inches more than that of the individual so well known to the public as the "King of the Gorillas." A young specimen, preserved in spirits, was also brought over, which was taken alive, and it was fondly hoped would be the "lion" of the Zoological Gardens this season.*

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* Since the above was written, another gorilla (dead) has arrived at Liverpool from the Giboon, and will probably be added to the zoological treasures of the town museum.

M. de Chaillu has an illustration in his book which represents himself and a number of blacks contemplating a fallen gorilla. One day last month we could have presented him with a companion picture.

On the floor of the sale-room of a Liverpool broker, to whose care the corpse of the illustrious visitor was confided, there stood a box-coffin, about five feet long, containing its skeleton (the animal itself is 5 feet 11 inches high, the skeleton not being stretched at full length), and by its side lay the skin; the hands exceeding in size, and resembling in appearance, a large pair of gloves with external fur, and bare skin on the palm, &c. All round stood a number of curious and wondering "Liverpool gentlemen," brokers, and merchants, with open eyes and *closed nostrils;* whilst Mr. Moore, the curator of the

Birds of Paradise.—These wonderful birds, inhabitants of the inaccessible and dangerous swamps of New Guinea, have at length been comfortably located in the Zoological Gardens of London. One specimen only had previously been known in this country, which many years since lived at Windsor, as a pet of the late Princess Augusta. For the present grand addition to the unrivalled collection in the Regent's Park, the society and the public are indebted to Mr. A. R. Wallace, well known in connection with his zoological explorations. With infinite difficulty he succeeded in procuring two specimens, both males unfortunately, of the *Paradisea papuana*, which have been transported safely, and deposited in the gardens in a healthy condition. The loveliness of the plumage of these birds is no guarantee of sweetness of voice, and their harsh *caw* is said to resemble that of the crows, to which family they are nearly allied.

The Pythoness.—Since the arrival of the Hippopotamus, no animal has caused so general an interest as the female Python, which was long busily engaged in incubating her pile of eggs. We abstained from noticing it in our last number, preferring to await the result. The Indian Python (*Python bivittatus*), which, in 1841, hatched eight of its eggs at Paris, incubated fifty-six days, and the careful observations made on that occasion are interesting as compared with the recent event. Our python deposited its eggs on the 13th January, and commenced at once its self-imposed duties. Having sat for six weeks without taking food, the animal came off on the 4th of March, for the purpose of changing its skin, and remained all night away from her eggs. Towards the end of March, after the reptile had been nine weeks upon the eggs, it was deemed desirable to remove them, which was done with much difficulty, when it was found that they were entirely decomposed, so much so as to render it impossible to say how long they had lost their vitality, though they are believed to have been impregnated. The whole circumstance is extraordinary, and not the least remarkable part of it is the increased temperature evolved by the reptile during the process, to all appearance for the purpose of vivifying the eggs. M. Valenciennes states, that in the case of the Indian Python at Paris, a special heat was developed, which gradually *diminished* as the eggs approached hatching. Although the experiment in the recent case was incomplete, Dr. Sclater is of opinion that this view is not confirmed. The fact, however, of a special heat attributable to the process of incubation is undoubted. The male and female python were both kept in the same den, the temperature of which varied from 58° to 66°. The temperature of the male was usually between 10° and 11° above this, while the tempe-

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museum, was, in a most business-like manner, measuring the monster's proportions as he lay in his narrow coffin.

Our broker-friend informed us, that "if this sample is approved, a regular supply will be forthcoming;" so we recommend M. du Chaillu to "realize," if he has any stocks on hand.

The animal above referred to killed the native who inflicted the mortal wound. The black speared him in the breast, and approaching too soon to withdraw the spear, was seized by the gorilla, and instantly squeezed to death in his terrible embrace.

We hope shortly to be able to communicate further details concerning the habits of these animals.

rature, as ascertained by a thermometer placed between the coils of the female in the beginning of March, was as much as 20° above that of the male. The pythoness has abstained from food for the enormous period of thirty-six weeks.

Bite of the Adder.—It is not often we hear of fatal effects resulting from the bite of our indigenous snakes. The *British Medical Journal* quotes a case from the *Sussex Express*, of a little boy, who, not being properly attended to, is said to have succumbed to the poison on the second day.

Parthenogenesis of the Honey-bee.—Mr. T. W. Woodbury, of Mount Radford, Exeter, has confirmed the theory first propounded by Dzierzon of Karlsmarkt, that a Virgin Queen can breed drones. The *Journal of Horticulture* of October 22 contains an account of his experiments which appear to be perfectly conclusive.

New Animals.—No division of the animal kingdom yields so many novelties as the classes of birds and insects. Mr. G. Lawrence describes six new species of birds from Panama, belonging to the families of thrushes and shrikes. Dr. Jerdon has met with several new species in Upper Burmah. Dr. G. Hartlaub has described several new species from Cape Colony; and Mr. J. H. Gurney, M.P., from Natal, while the indefatigable Dr. Sclater, in whose "Ibis"* the above may be found, has not been idle. Mr. Arthur Adams continues his contributions to the Molluscan Fauna of the Sea of Japan. Mr. Bates, well known for his zeal in collecting insects, still enriches the list of longicorn beetles inhabiting the valley of the Amazons; and Mr. T. V. Wollaston, of Madeiran fame, has extended his researches to the coleoptera of the Canary Islands. Several new fishes have also been obtained from the Pacific coast of central America.

New and rare British Animals.—The British fauna, far from being exhausted, continues to receive accessions in various departments. It is interesting to observe, that the most predacious of our quadrupeds is not yet extinct, the wild cat having been recently met with on the property of the Earl of Seaforth, in Inverness-shire. The skull of a new species of Pilot-whale (*Globiocephalus*), dredged up at Bridport, Dorsetshire, has been described by Dr. Gray, and figured in the "Annals of Natural History." The rare and beautiful Crane (*Grus cinerea*) has been recently met with (and, of course, *killed*) near Hartlepool. Mr. O. Pickard, Cambridge, the indefatigable spider-hunter, has added ten new species to the British list, and the veteran zoophytologist Joshua Alder has made large additions to the list of Hydroid Zoophytes by his explorations on the coast of Northumberland.

Mesozoic Forms of Life in Australia.—Under this title Professor Owen announces the very interesting fact of the discovery by the dredge, in eight fathoms, of a living encrinite, of a rose-pink colour, fading to white; whose stem, attached to a stone, was six inches long, the arms one and a half inch. This remarkable animal was found by Mr. J. S. Poore in King George's Sound, Western Australia.

The Zoological Collections in the British Museum, it has been decided, shall *not* be removed to South Kensington, according to the proposals of Professor Owen. Mr. Osborne placed the Professor's plans in so obnoxious a light, that

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* We recommend the "Ibis," an ornithological journal, edited by Dr. Sclater, to our naturalist readers.

the question was negatived in the House, and the Government defeated by the unusually large majority of 92.

Faunal Collections.—Professor Agassiz, in a report to the Senate and House of Representatives, urges the importance of special district collections to facilitate the study of the species, and their geographical distribution. These collections, he says, bring distinctly before the eye the character of the inhabitants of different parts of the world in their natural combinations, and that in a far more impressive manner than could possibly be attained by a mere nominative enumeration of species.

Death of Schrœder Van der Kolk.—This eminent physiologist, Professor of Medicine in the University of Utrecht, expired on May 1st. He was highly esteemed in Holland, and a member of several illustrious orders of knighthood. A letter, describing the event, says of him: "Utrecht has thereby lost one of its most estimable citizens, the University one of her ornaments, society one of her greatest benefactors, science one of her most devoted cultivators, his numerous household a loving father, their mainstay and their hope!"

LIST OF ENGLISH AND FOREIGN POPULAR WORKS ON SCIENTIFIC SUBJECTS, PUBLISHED DURING THE YEAR ENDING JULY 1, 1862.*

Astronomy :—

*Barrol's, J. A., "Atlas of Cosmos," with plates, in parts, folio. (French.)

*Biot's, J. B., "Studies in Indian and Chinese Astronomy." (French.)

Chambers's, G. F., "Handbook of Descriptive and Practical Astronomy." Post 8vo. Murray.

Drayson's, Capt., "Common Sights in the Heavens," &c. Chapman & Hall.

Lewis's, Sir G. C., "Historical Survey of the Astronomy of the Ancients." Parker, Son, & Bourne.

*Guérin's "Indian Astronomy, according to the Doctrines and Writings of the Brahmins, with an Explanation of the Chief Astronomical Monuments of Egypt and Persia." Plates. 8vo. (French.)

*Maedler's, J. H. V., "Total Eclipses of the Sun, with especial Reference to the Eclipse of July 18, 1860." 9 plates. (German.)

Mitchell's, O. M., "Orbs of Heaven," and "Popular Astronomy." Crown 8vo. Routledge.

Read's, W. T., "Popular and Mathematical Astronomy, with Formulæ of Trigonometry." Crown 8vo. Longman.

†Stehr, L., on "The System of the World."

Botany :—

Archer's, T. C., "Vegetable Products of the World in Common Use." Illustrated. Royal 16mo. Routledge.

Cooke's, M. C., "Manual of Structural Botany." Illustrated. 18mo. Hardwicke.

Cooke's, M. C., "Manual of Botanic Terms." Illustrated. Fcap. 8vo. Hardwicke.

Cooke's, M. C., "Plain and Easy Account of British Fungi." With 24 coloured plates. Fcap. 8vo. Hardwicke.

Grindon's, L. H., "Manual of Plants, British and Foreign." Pamplin.

Glenny's, George, "Properties of Fruits and Vegetables," "Guide to Judges," &c. Fcap. 8vo. Houlston.

*Hildebrand's "Distribution of Coniferæ, Recent and Fossil." Plates. (German.)

Macmillan's, "Foot-notes from the Page of Nature." Fcap. 8vo. Macmillan.

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* All works in this list marked with an asterisk (*) are advertised for sale by Messrs. Williams and Norgate, Henrietta-street, Covent Garden, in the language in which they are published abroad; those marked thus (†) are sold by Mr. D. Nutt, 270, Strand.

Darwin's, Chas., "Intercrossing of Orchids by Means of Insects." Murray.

*Maeller's, C., "Vegetable Kingdom." Illustrated. (German.)

†Moquin-Tandon's "Elements of Medical Botany."

*Schleiden's, M. J., "Elements of Scientific Botany." 250 wood engravings, 5 plates. (German.)

Seibert's "Popular Botany, in relation to Plants of the Forest; Economic, Technical, and Medical Botany." (German.) Leipsig: C. F. Winter.

Maling's, Miss E. A., "Indoor Plants; and how to grow them; for the Drawing-room, Balcony, and Greenhouse." Fcap. 8vo. Smith & Elder.

Lankester's, Mrs., "Wild Flowers worth Notice." Illustrated. Fcap. 8vo. Hardwicke.

Sowerby & Johnson's "British Poisonous Plants." Illustrated with 32 coloured plates. Post 8vo. 2nd edition. Van Voorst.

Chemistry:—

Heaton's, C. W., "Threshold of Chemistry." An Experimental Introduction. Post 8vo. Chapman & Hall.

Odling's, W., "Manual of Chemistry—Descriptive and Theoretical." 8vo. Longman.

Knapp's "Chemical Technology." Baillière.

*Hiller's "Manual of Chemistry." 150 engravings. (German.)

*Oppler's "Handbook of the Manufacture of Mineral Oils and Dyes from Coal, Wood, Turf, Petroleum, and other Bituminous Substances." (German.)

Meller's, D. W. A., "Elements of Chemistry." 2nd edition. Parker, Son, & Bourne.

Gmelin's "Handbook of Chemistry." 2nd edition revised. Harrison.

Piggot's, Dr. A. Mowden, "Chemistry and Metallurgy of Copper." New edition. Illustrated. 12mo. Philadelphia.

Thomson's, Dr. R. D., "School Chemistry. Practical Rudiments of the Science." 2nd edition. Fcap. 8vo. Longman.

Kirchoff's "Researches on the Solar Spectrum and the Spectra of the Chemical Elements." (Translated by H. E. Roscoe.) Macmillan.

Faraday's, M., "Lectures on the Chemical History of a Candle." Edited by W. Crookes. Fcap. 8vo. Griffin & Co.

Bowman's, J. E., "Practical Chemistry." Longman.

Geology, Mineralogy, Metallurgy, and Palæontology:—

Bristow's, Henry W., "Glossary of Mineralogy." Post 8vo. Longman.

Owen's, Richard, "Palæontology. A Summary of Extinct Animals." 2nd edition. 8vo. Black.

Wallace's, Wm., "Laws regulating the Deposition of Lead Ore in Veins." 8vo. Stanford.

Percy's, John, "Metallurgy: the Art of Extracting Metals from their Ores." 8vo. Murray.

*Delesse's "Studies on the Metamorphism of Rocks." (French.)

*Fremontel's "Fossil Polyparies," &c. 8vo. (French.) Paris.

*Leymerie's "Elements of Mineralogy and Geology." 12mo. (French.) Paris.

*Quenstedt on "The Epochs of Nature." 800 Engravings Royal 8vo. (German.)

*Unger's, F., "Views of the Ideal World;" edited by S. Highley. 4to.

Fairbairn's, Wm., "Iron: its History, Property, and Manufacture." Post 8vo. Black.

*Dechen's "Geological Guide to the Siebengebirge (Rhine)." (German.)

*Oldham's "Palæontologica Indica."

Smith's, A., "Blowpipe Character of Minerals." Edited by Houghton & Scott. 8vo. Williams & Norgate.

Pepper's, John H., "Playbook of Metals." New edition. Crown 8vo. Routledge.

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Jukes's, J. B., "Student's Manual of Geology." New edition. Illustrated. Crown 8vo. Black.

Scrope's, G. P. "Volcanoes; the Character of their Phenomena," &c. Revised and enlarged. 2nd edition. 8vo. Longman.

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*Meyer's, G., "Manual of the Psychology and Anatomy of Man." 356 plates. (German.)

*Follin's "Elementary Treatise on Pathology." 80 engravings. 8vo.

*Frarière's, De, "Material Influences during Gestation upon the Moral and Intellectual Predispositions of Children." (French.)

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*Drion & Fernet's "Elementary Physics." 100 cuts. (French.)

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Schoedler's "Treasury of Science, Natural and Physical." Translated by Dr. Medlock. Crown 8vo. Griffin.

†Emsmanor's "Elementary Physics." (German.)

*Schellen, H., "On the Electro-magnetic Telegraph." New edition. 252 engravings. (German.)

Zoology :—

Greene's, Prof. J. R., "Manual of Cœlenterata." Fcap. 8vo. Longmans.

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*Hartland's "Ornithological Contributions to the Fauna of Madagascar." (German.)

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*Quatrefages' "Unity of the Human Species." (French.)

*Rathke's "Development of Vertebrata." Posthumous, with Introduction, by Kœlliker. (German.)

Couch's, Jonathan, "History of Fishes of the British Islands." Vol. I. Royal 8vo. Groombridge.

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